Physiological Significance of Ethrel (2-Chloroethyl Phosphonic Acid) and Nitrogen in Relation to Growth and Metabolism of Mustard under Irrigated and Non-Irrigated Conditions

ABSTRACT

THESIS

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DEPARTMENT OF BOTANY
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Physiological Significance of Ethrel (2-Chloroethyl Phosphonic Acid) and Nitrogen in Relation to Growth and Metabolism of Mustard under Irrigated and Non-Irrigated Conditions

Mohmad Ramzan Mir

Abstract of the thesis submitted to the Aligarh Muslim University, Aligarh, India for the degree of **Doctor of Philosophy** in **Botany**.

The present thesis comprises six chapters. Chapter 1 deals with the importance of the problem. Lacunae in the understanding of the problem and justifications for undertaking the present study have been put forth.

Chapter 2 is review of literature. Relevant available literature pertaining to individual as well as combined effect of plant growth regulators especially ethylene sources with nitrogen on crop growth and development has been given in this chapter.

Chapter 3 describes the details of the material used in the study and methods employed in determining observations carried out in the experiments. Relevant information on meteorological and edaphic data has been included.

In Chapter 4, the results obtained in the experiments which were found significant at $P<0.05$ have been recorded in detail.

In Chapter 5, significant results have been discussed in the light of earlier reported findings. Possible explanations of the data obtained have also

been given to reach a conclusion. The results of the five field experiments are summarized below.

Experiment 1 (1998-99) was conducted under irrigated conditions to study the response of two cultivars (Alankar and PBM16) of mustard (*Brassica juncea* L.) to leaf-applied ethrel at 60d after sowing (flowering stage). Alankar is a well-established cultivar and accepted by the mustard growers for a decade, whereas PBM16 is a newly released. This was a factorial experiment conducted according to randomized complete block design. The response of the cultivars to ethrel treatments was assessed by determining growth and biochemical characteristics at 80 (pod fill), 100 (pod maturity) and 120d (harvest) after sowing. Physiological characteristics were studied at 80 and 100d after sowing. Yield and quality characteristics were determined at harvest. Growth characteristics were plant height, plant leaf area, leaf area index, specific leaf area, specific leaf weight, plant dry weight and dry weights and per cent dry weight distribution in leaf, stem and pod, leaf fresh weight, leaf turgid weight and leaf relative water content. Physiological characteristics were, rate of photosynthesis, stomatal conductance, internal CO_2 concentration, transpiration rate, carboxylation efficiency, photosynthetic water use efficiency, and plant water use efficiency. Biochemical characteristics included N content and N accumulation in plant. At harvest, yield characteristics studied were, number of pods per plant, number of seeds per pod, 1000 seed weight, seed yield,

biological yield, harvest index and oil yield. The oil was assessed for acid, iodine and saponification values.

Among five concentrations of ethrel (0, 100, 200, 400 and 600µL/L) applied, 200µL/L was found superior over others in increasing the plant characteristics studied. The concentration less than 200µL/L was found less effective, whereas concentration higher than 200µL/L proved inhibitory. Spray of 200µL/L ethrel affected growth of the plants and increased total leaf area per plant. Thus, the increase in photosynthesising surface area led to increase in photosynthesis and CO_2 accumulation, which resulted in increased plant dry weight. The other effects of ethrel spray was noted in improved source-sink relationship, as seen in increase in per cent pod dry mass in ethrel-treated plants. More of the flowers developed into pods, evident from higher pod number and seed yield in ethrel-treated plants compared with water-sprayed control. The oil quality was also improved with 200µL/L ethrel spray.

Comparison of the cultivars showed that Alankar established its superiority over PBM16. Growth, physiological, biochemical, yield and quality characteristics were found superior in Alankar than in PBM16. Interaction effect between cultivar and ethrel spray was non-significant for most of the plant characteristics. This suggests that the two cultivars responded similarly to ethrel spray.

Experiment 2 (1998-99) was a factorial randomized complete block design conducted on the same lines as Experiment 1 but under non-irrigated

conditions. The scheme of the treatments, design of the experiment, ethrel spray treatments and cultivars of mustard were also similar as described for Experiment 1. The observations recorded at different sampling stages were similar to Experiment 1. In this experiment, it was noted that ethrel spray at 200µL/L concentration was more effective than any other concentrations used. The effect of the spray was manifested through changes in various characteristics as described for Experiment 1. Alankar cultivar surpassed PBM16 in performance.

Combined analysis of the two experiments showed that the factors irrigated and non-irrigated were non-significant. Ethrel spray under irrigated and non-irrigated conditions was equally effective. The two cultivars also behaved similarly in the two conditions of irrigation.

Experiment 3 (1999-2000) was a factorial randomized complete block design conducted under irrigated conditions to study the effect of leaf-applied 0, 100 and 200µL/L ethrel on the performance of Alankar cultivar of mustard (the cultivar was selected on the basis of Experiment 1) grown with soil-applied 0, 40, 60 and 80kg N/ha. Ethrel spray application was done at 60d after sowing (flowering stage) and performance of the crop was assessed by determining various plant characteristics at 80 (pod fill), 100 (pod maturity) and 120d (harvest) after sowing. Growth characteristics were those studied in Experiment 1. Among physiological characteristics, 1-aminocyclopropane-1-carboxylic acid content, ACC oxidase and ethylene evolution were also studied

in addition to the characteristics studied in Experiment 1. Among biochemical characteristics, leaf nitrate reductase activity was also studied in addition to the determination of N content and N accumulation in plant. Among yield characteristics, seed N, nitrogen harvest index and nitrogen yield potential were also studied in addition to the yield characteristics studied in Experiment 1. Quality characteristics were similar as in Experiment 1.

Ethrel at 200μL/L concentration and nitrogen at 80kg N/ha registered significantly superior values as compared to other treatments. Ethrel (200μL/L) enhanced growth, physiological, biochemical, yield and quality characteristics. In this experiment, it was found that the effect of 200μL/L ethrel was maximal when plants received soil-applied 80kg N/ha. This combination (200μL/L ethrel and 80kg N/ha) enhanced plant leaf area, photosynthesis, CO_2 accumulation and plant dry weight. Water relations characteristics such as leaf fresh weight, leaf turgid weight and leaf relative water content were also enhanced by 200μL/L ethrel x 80kg N/ha. Pod dry weight was maximal with 200μL/L ethrel x 80kg N/ha, which showed higher translocation of dry matter towards sink (pods). Among physiological characteristics, rate of photosynthesis, internal CO_2 concentration, transpiration rate, photosynthetic water use efficiency, water use efficiency, 1-aminocyclopropane-1-carboxylic acid content and ACC oxidase were maximal in 200μL/L ethrel x 80kg N/ha. Plants grown with sufficient soil-applied N (80kg N/ha) responded to the ethrel (200μL/L). However, if soil-applied N was

less than 80kg N/ha, the effect of ethrel spray was not prominent. The increased vegetative growth due to ethrel (200µL/L) spray made the plant to extract more of the soil N and was reflected in N content and accumulation and increased growth, physiological, biochemical and yield characteristics. The calculated nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen-use efficiency showed that nitrogen use was better when plants were treated with the 200µL/L ethrel spray. Seed yield, oil yield and nitrogen yield potential were increased and were maximal with 200µL/L ethrel x 80kg N/ha.

Experiment 4 (1999-2000) was a factorial randomized complete block design conducted simultaneously with the Experiment 3 under non-irrigated conditions. The scheme of the treatments, ethrel spray concentrations and soil-applied nitrogen were same as in Experiment 3. The data on growth, physiological, biochemical, yield and quality characteristics recorded were those mentioned for Experiment 3. Individual effects of 200µL/L ethrel spray, soil-applied 80kg N/ha and their interaction proved best for most of the plant characteristics. The response of the plant to ethrel and nitrogen treatments was similar as found in Experiment 3.

Combined analysis of Experiments 3 and 4 showed that the response of the plant to ethrel spray, soil-applied nitrogen and their interaction was uniform irrespective of the irrigation conditions. The data on plant characteristics under irrigated and non-irrigated conditions were non-significant. The data suggests that 200µL/L ethrel spray on plants grown with soil-applied 80kg N/ha may be

used for improving mustard cultivation irrespective of the conditions of irrigation.

Experiment 5 (2000-2001) was a factorial conducted according to randomized complete block design. In this experiment applications of 0 and 200µL/L ethrel or 1mM silver thiosulphate were done as foliar spray at 60d after sowing (flowering stage) on mustard cultivar Alankar grown under irrigated and non-irrigated conditions. Plants were raised with uniform soil application of 80kg N/ha. This experiment was based on the findings of Experiments 3 and 4. The response of the plants to ethrel spray treatment was confirmed in this experiment with the use of silver thiosulphate spray treatment, as silver thiosulphate application inhibits ethylene action. The observations recorded at 80, 100 and 120d after sowing included growth (plant leaf area plant dry weight), physiological, biochemical, yield and quality characteristics were similar to Experiments 3 and 4. Maximum response was noted with 200µL/L ethrel spray treatment. However, silver thiosulphate spray inhibited the ethylene action and ethrel effect was not observed. The interaction effect of spray and irrigation was found non-significant. The results of the experiments suggest that response of the plant to ethrel treatment seen in Experiment 1–4 was manifested through the action of ethylene.

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Dedicated to My Cate uncle

"Who had offered his finger when I attempted to stand on my legs"

And My Parents

"Whose blessings have sustained me through this work"

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CERTIFICATE

This is to certify that the thesis entitled **Physiological Significance of Ethrel (2-Chloroethyl Phosphonic Acid) and Nitrogen in Relation to Growth and Metabolism of Mustard under Irrigated and Non-Irrigated Conditions** submitted for the degree of **Doctor of Philosophy** in **Botany** is a faithful record of bonafide research work carried out at the **Aligarh Muslim University, Aligarh** by Mr. **Mohmad Ramzan Mir** under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

(NAFEES AHMAD KHAN)

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Mohd Ramzan

(Mohmad Ramzan Mir)

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CHAPTER–1
INTRODUCTION

INTRODUCTION

Agriculture is backbone for the development of Indian economy It contributes nearly 30 per cent of domestic production and employs about 70 per cent of the people The Government of India is aimed at achieving and maintaining agricultural growth rate of 4 per cent Among several crops grown, oilseeds occupy an important place in agricultural produce all over the world, so as in Indian agriculture Oilseeds hold about 13 per cent of country's gross cropped area, contributing 10 per cent of all agricultural products and 5 per cent to Gross National Productivity Oilseeds cultivation is carried out across the country in an area of about 26 million hectares Rapeseed is cultivated in 3 73 million hectares in India, which keeps it to the third position in the world just behind the Canada and China

Four major crops, soybean, sunflower, rape and palm provide over 70 per cent of the vegetable oil and cottonseed, coconut seed and groundnut supply the remainder Oilseed *Brassica* accounts for approximately 10 per cent of the total world oilseed production and 14-15 per cent of the total vegetable oil production (Downey and Rimmer, 1993) There are few non-conventional sources of oil, which are employed to increase the resources of vegetable oil Most important of them are rice bran and maize germ

The importance of the oilseed is because of fats contained in their seeds, which provide 2 5 times more calories than carbohydrates Fat is also an important constituent of cell membrane and serves as a precursor for a variety of biologically active compounds collectively known as eicosanoids (e g prostagladins, thromboxanes and leukotrienes) It also helps in transport of fat-soluble vitamins, A, D, E and K in human body (Anonymous, 1993) Most vegetable oil is used directly in human diet as cooking of salad oil and margarine or indirectly processed products such as shortening and

confectionery. Besides the use of oil, oilseeds by-products such as protein meal from seeds and hulls of seeds are used as animal feedstuff and in making of insulation boards. About 20–30 per cent of oil is used for non-edible purposes, e.g. in the production of soaps, detergents, lubricants, plastics, resins, paints, varnishes, cosmetics and as precursors to a wide range of chemicals.

India recorded a spectacular increase both in area and production of oilseeds during the last few decades. The production increased from 11 million tonnes to 22 million tonnes during the last decade in an effort called Yellow Revolution. However, considering the area and production of oilseeds in world's scenario, India produces only about 7 per cent of world's edible oil with about 35 per cent of the world's area under oilseed cultivation. With this limited area and production of oilseeds, it has to feed about 16 per cent of the total world's population. To meet the daily requirements of oils and fats of 18g per day, India has to import edible oil every year on large scale, which causes burden on our limited foreign resources.

The oilseeds production in India is restricted due to several factors. For example: (i) more than 75 per cent of the farmers have small or marginal holdings of less than two hectares (ii) only 15 per cent of area under oilseed is irrigated as compared to 72 per cent under wheat and 44 per cent under rice (iii) absence in advancement of agricultural techniques for high yielding varieties, post harvest technology and proper processing facilities (iv) no genetically modified oilseeds are released for cultivation (v) lower number of flowers (about 68 per cent) develops into pods (vi) pod shattering is a particular problem in oilseed rape, which accounts to an average annual losses of about 20 per cent (Downey and Robbelen, 1989). Seeds may be lost to the extent of 10,000 seeds/m^2 (Lutman, 1993). (vii) hormonal imbalance during sink development, which may be the cause of flower drop and pod shattering and improper source-sink relationship.

With the limitation in increasing the land under cultivation, the focus, thus is on increasing the productivity of available land.

Nitrogen affects favourably growth, development and yield of crops (Marschner, 1986; Khan *et al.*, 1990; Samiullah *et al.*, 1990; Khan *et al.*, 2000; Dodd, 2001; Khan *et al.*, 2001) as this nutrient forms the building blocks of macromolecules in cell (Salisbury and Ross, 1994). Nitrogen application brings about increase in water use efficiency through increase in soil moisture extraction at sub soil surface and increase in growth at upper ground level (Saran and Giri, 1990; Vyas *et al.*, 1995; Thakral *et al.*, 1997; Zaman and Choudhri, 1998; Dodd, 2001). However, continuous application of nitrogen has environmental as well as economic limitations. For example, about half of the nitrogen unavailable to the crops (Greenwood, 1982) remains in the soil and washed away with water to increase the biological productivity of the water bodies causing a well-known eutrophication phenomenon. Moreover, excessive use of nitrogen exerts a pressure on its production and involves possibility of its high prices. Besides subsidy on nitrogen by the Government, a majority of small crop growers (75 per cent) still face difficulty in procuring the nitrogenous fertilizers at appropriate time. It is, therefore, a challenge before the research scientists to find out options, which reduce the input of nitrogen without affecting seed yield. In this regard, methods for better management of applied nitrogen through higher N-use efficiency may be an answer. If physiological basis of nitrogen utilization efficiency with increase in the sink strength and better source-sink relationship is developed, then problems discussed earlier would find solution and physiological traits may be developed as a biochemical tool. In the preceding pages, it was mentioned that lower number of flowers (about 68 per cent) develops into pods due to hormonal imbalance. The use of plant hormones as foliar spray at appropriate stages has shown to affect flowering and pod formation (Wareing and Phillips, 1981; Cheema *et al.*, 1987; Rajala and Peltonen-Sainio, 2001). Further, researches

carried out in the author's laboratory have shown that plant growth regulator, gibberellic acid, has potential of utilization of nitrogen, phosphorus, potassium and sulphur from the soil, increasing the growth and crop productivity (Ansari, 1996, Khan, 1996a, Khan *et al*, 1996, Khan, 1997, Khan *et al*, 1997, 1998, 1999, Mobin, 1999, Khan *et al*, 2001) Few studies on ethrel have also shown that it brings about increase in photosynthetic capacity and yield of mustard (Khan, 1996b, 1998, Khan *et al*, 2000) Other workers have also documented role and regulation of ethylene in plant growth and development (Abeles *et al*, 1992, Mattoo and White, 1991, Mattoo *et al*, 1997) In the present thesis, efforts were made for extensive examination of the role of ethylene (applied as ethrel) in physiology and metabolism of nitrogen in mustard (*Brassica juncea* L Czern & Coss) Five field experiments were conducted to accomplish the following objectives

1 To study the effect of leaf-applied ethrel on growth, physiology, yield and quality characteristics under irrigated and non-irrigated conditions
2 To study the effect of leaf-applied ethrel on growth and physiology of mustard grown with nitrogen levels
3 To study the relationship of nitrogen utilization efficiency of mustard with ethylene evolution
4 To test the hypothesis that ethylene has a central role in mediating plant responses with the use of ethylene action inhibitor silver thiosulphate

CHAPTER–2
REVIEW OF LITERATURE

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REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Introduction

Indian agriculture has progressed a long way to become a significant exporter of a diversified basket of agricultural commodities. Persistent efforts have been made to harvest a larger portion of the land to agricultural purpose and for induction of new technology. In post-independent India, agriculture has been growing at a rate of about three per cent per annum, while food grains production is increasing by 1.67 per cent, which falls short of population growth of 1.80 per cent.

A spectacular rise in food grains production has been observed since 1949-50. It is estimated that the production of cereal has gone to 206 million tonnes during 1999-2000. If acreage production of cereal crops is considered, rice ranks first. With an area of 44 million hectare that produces 88 million, this crop is a major contributor amongst cereal crops. Wheat and other cereal crops occupy lower position in terms of production.

The Indian oilseed scenario has also undergone a significant transformation due to contributions of oilseeds production technology, expansion in cultivated area, price support policy and institutional support. In particular, the set up of the Technology Mission on Oilseed in 1986 played a major role. The role of technology in fostering and sustaining the oilseeds production is vast. The self-sufficiency in oilseed has been possible only due to economically viable and sustainable technology. Since oilseeds are considered as hardy crops, they are mostly grown under moisture and nutrient scarce conditions that may limit the crop productivity. In India, agro-ecological conditions are such which favour growth of nine oilseeds crops. These are seven edible oilseeds, namely groundnut, rapeseed-mustard, soybean,

sunflower, safflower, sesame and niger and two non-edible castor and linseed, apart from a wide range of other minor oilseeds and oil bearing tree species.

With a production of 24 million tonnes during 1996-97, the country accounted for 9.7 per cent of the global oilseeds production (about 250 million tonnes). Indian vegetable oil industry achieved domestic turnover of Rs. 35,000 crores compared to international trade in import of vegetable oil and exports of oil meals and castor oil, which accounts to Rs. 65,000 crores.

The expansion in area under oilseeds has been main reason of increase in oilseeds production, but further scope of area expansion is meagre. Therefore, the productivity growth should take a lead in bridging the demand and supply gap. However, there are several constraints in increasing the productivity of oilseeds. These may be biotic and abiotic, on-farm and off-farm, technological and non-technological. With about 25 per cent of the area under irrigation, oilseeds are subjected to vagaries of monsoon resulting in lower yields compared to irrigated wheat and rice. This warrants limited and protective irrigation at least during critical stages of crop growth. Besides, several other constraints like continuous cultivation of oilseeds without proper crop rotation, low level of management adopted by small and marginal farmers, poor post-harvest technology and inadequate marketing support and weak technology transfer add to the problems of low crop productivity. Researches are done to overcome most of the constraints related to technology, in term of genetic improvement, efficient agronomic management, pest management, and post-harvest technology and to improve oilseeds crop production. As per study based on the data available from the Frontline Demonstration Project under the Oilseeds Production Programme, the mean yield of improved technology of oilseeds realizable on farmers' field is 1545 kg/ha, while the national average yield is of the order of 794 kg/ha. There exists a realizable yield gap of 751 kg/ha, which accounts for nearly about 95 per cent of the existing national average yield. In other words, an additional production of the order 16.27

million tonnes need to be added to the current oilseeds production in the country from the existing area under oilseeds. Oilseeds remained almost neglected during the green revolution phase in India in terms of total output

The languid production of oilseeds has converged the attention of agricultural scientists to innovate and implement the improvised methods for boosting the yield through proper nutrient management. In this context, *inorganic nutrients (concerned with acquisition of mineral elements from the* soil) found to be immensely remarkable The green revolution of India owes much to this form of nutrition. Now, when we are on the verge of entering in to the era of Ever Green Revolution, the investigations regarding application of nutrients need to be thoughtfully considered, which has largely been ignored

It may be emphasized that work carried out in relation to nutrient is voluminous and it is known that application of only few essential nutrients like, N, P and K alter the availability and uptake of other nutrients Among them nitrogen is a major nutrient and its availability in the rhizosphere has been found to enhance the yield and quality of seed crops (Ansari, 1990; Jeschke *et al* , 1992, Awasthi and Surajbhan. 1994, Sarkar *et al.*, 1999; Khan *et al.*, 2000, Dodd, 2001)

Water plays an important role in physiological processes of plants and its inadequacy results in depressed crop productivity around the world (Ludlow and Muchow, 1990, Nilsen and Orcutt, 1996, Singh *et al.*, 1996). Oilseed *Brassicas* (rapeseed and mustard) are generally grown on conserved soil moisture from monsoon rain, which is progressively depleted with the advancement of growing season Decline in relative water content because of reduced water availability brings about changes in morphological plant characteristics (Kumar and Bharti, 1988; Nilsen and Orcutt, 1996). A decrease in the rate of photosynthesis in leaves has been attributed to both stomatal and non-stomatal limitations (Graan and Boyer, 1990; Lauer and Boyer, 1992) Decreased photosynthetic rate is associated with a reduction in protoplast

and/or chloroplast volume (Santakumari and Berkowitz, 1990). Under low plant water status leaf chlorophyll content and stomatal conductance decreases causing reduction in photosynthetic rate. The net rate of CO_2 assimilation decreased as water stress developed in wheat (*T. aestivum*) (Lu and Zhang, 1999). Decrease in photosynthetic capacity during water stress in *Brassica juncea* could be ascribed to restricted CO_2 availability as a consequence of stomatal resistance to gas exchange (Sawhney *et al.*, 1996).

The area of the leaves developed to lesser extent when plants are exposed to low water status (Lu and Neumann, 1998; Pankovic *et al.*, 1999). Kumar and Elston (1993) reported that leaf area was reduced in both species of rape and Indian mustard under low water regime. Similar results were reported by Burke *et al* (1985), Kumar *et al.* (1994), Sardadevi *et al.* (1996). Leaf area index, crop cycle length and phenology determine the total dry matter production, yield and yield components under drier environments. Shoot is found to more sensitive to water than root growth in *Brassica juncea* (Pannu *et al.*, 1992; Sharma *et al.*, 1994).

Water availability affects the process of cell expansion via physical and metabolic changes (Taiz, 1984; Nonami *et al.*, 1997). Reduced rates of new cell production may make additional contributions to the inhibition of growth (Silk, 1992; Durand *et al.* 1995; Lecoeur *et al.*, 1995). Decreased water availability reduced leaf area index, relative water content, xylem potential, seed yield and harvest index in mustard (Sharma, 1992).

Nutrient uptake of plants decreased under water stress condition due to reduced transpiration. A decline in soil moisture has also been associated with a decrease in nutrient uptake (Tanguilig *et al.*, 1987) primarily caused by the physiological impairment of the active nutrient absorption and transport mechanism of the roots.

Amino acid accumulation has been shown to occur in a variety of monocots and dicots. One of the best-characterized osmoregulatory responses

is the accumulation of proline Water stress enhanced the proline content in mustard, wheat and Plantago To maintain uptake of water and nutrients under limiting water conditions, continuous proliferation of roots into new soil layer is important at the cell and tissue level (Nilsen and Orcutt, 1996)

Drought stress resulted in reduction in seed yield and was due to differential responses of yield contributing traits in species of rapeseed-mustard (*Brassica campestris* and *Brassica napus*) (Mathur and Wattal, 1996) Kumar *et al* (1994) reported that the seed yield reduction by water stress was because of decrease in the number of pods per plant and number of seeds per pod

Fertilizer application has been found to bring about marked improvement in water use efficiency with increasing fertility levels (Singh and Srivastava, 1996, Thakral *et al*, 1997) The role of N in photosynthetic capacity has long been recognized Nitrogen ensures the build up of chlorophyll (Evans and Terashima, 1988, Sage *et al*, 1990, Liu and Dickman, 1992) and increases the amount and activity of enzymes for leaf nitrogen content Sugiharto *et al* (1992) found a significant positive correlation between the photosynthetic capacity of leaves and their leaf nitrogen used for synthesis of components of photosynthetic apparatus

Nitrogen application enhanced soil moisture extraction and increased water use efficiency during larger leaf area without affecting water use during reproductive phase in mustard under different levels of stored soil moisture (Saran and Giri, 1990, Vyas *et al* 1995)

Water potential, relative water content, photosynthesis and concentration of photosynthetic pigments are known to be influenced by growth regulators under stress conditions (Kumar and Bharti, 1988, Cliquet *et al*, 1991, Sairam *et al*, 1991, Dayal *et al*, 1993) Growth regulators application under moisture stress also helps in preserving water balance of the plant by closing the stomata and canopy modification and thereby reducing the rate of transpiration which ultimately results in protecting the enzyme proteins and cell organelles for

biochemical activities (Leitch and Kuat, 1999, Sanvicente *et al*, 1999) Along with the proper nutrition and water management, hormonal balance if made at particular developmental phase this would be an additional benefit for crop yield A group of chemicals that modify hormonal balance is thought to be plant growth regulators

Keeping in view the specific nature of the problem of the thesis, a general account of the plant growth regulators has been given with special emphasis of ethylene and impact of ethylene releasing compounds on aspects of growth and development of plants

2.2 Plant Growth Regulators

The definition of phytohormones accepted by most plant physiologists is similar to that developed for animal hormones Pincus and Thimann (1948) defined it as *a plant hormone is an organic compound synthesized in one part of a plant and translocated to another part, wherein very low concentrations it causes a physiological response* and to distinguish it from animal hormone it was named phytohormone and the substances which regulate growth are called 'growth regulators' (Sircar, 1971) Hormones are effective at internal concentrations of about 1μM, whereas other metabolites necessary for growth and development are usually present at concentration 1 to 50μM The precise location of synthesis of phytohormones is uncertain but actively growing leaves, fruits and developing seeds are thought to be active sites of synthesis of phytohormones However, it appears that all tissues have potential to produce any of the phytohormones, which are transported via the xylem or phloem and by diffusion such as in the case of ethylene They occur in plants as free and conjugated forms The latter are conjugates of sugars, amino acids and possibly peptides The free forms are generally considered to be biologically active, while conjugates are viewed as functioning in controlling levels of the more active forms of transport and storage

The plant hormones are extremely important agent in the integration of developmental activities. Environmental factors often exert inductive efforts by evoking changes in hormone metabolism and distribution within the plant. Apart from this, they also regulate expression of the intrinsic genetic potential of plants. The mechanism of action of phytohormones is poorly understood. However, several mechanisms or combinations may be operative. Control of genetic expression has been demonstrated for the phytohormones at the transcription and translational levels. Also, hormones receptors binding proteins have been identified on membrane surface that are specific for some phytohormones. The type and abundance of these proteins appear to be important in determining the sensitivity of the tissues to phytohormones differing in concentrations.

The chemical control of plant growth and through the use of a plant growth hormone is a common practice to make a plant more commercially acceptable. A number of synthetic compounds control shoot growth in higher plants without being phytotoxic or causing malformation or damage (Cathey, 1964; Salisburry and Ross, 1994). Some of these substances have found application in agricultural practice (Nickell, 1982; Salisburry and Ross, 1994). They have been shown to be involved in the regulation of photosynthesis and the movement of the photosynthetic products from their site of synthesis in the leaf to their site of accumulation (Patrick, 1982; Thomas, 1986; Patrick and Steains, 1987; Pereto and Beltran, 1987; Khan, 1996a, b; Khan *et al.*, 1997; 1998; 2000; 2001).

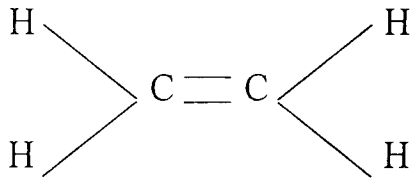
2.3 Ethylene as Plant Growth Regulator

The most commonly used and best understood group of plant growth hormones consist of those which regulate the production of ethylene (Yang and Hoffman, 1984; Abeles *et al.*, 1992). Ethylene is believed to control every aspect of plant growth and development.

2.3.1 Ethylene

The Russian botanist Neljubow (1901) was the first to recognize the growth regulatory properties of ethylene. Later on in 1930 it was recognized to have a wide variety of effects on plants and it was until 1934, when Gane in England first obtained positive proof that ethylene was a natural plant product.

Ethylene (ethane according to the IUPAC system of nomenclature) has the formula $H_2C = CH_2$ (MW 28.05). It is a gas (m.p = -169.15°C; b.p = -103.71°C). It is colourless with ether like smell and is lighter than air (density of ethylene at 0°C and 1 atmosphere = 1.260g L^{-1}; density of dry air at 0°C and 1 atmosphere = 1.293g L^{-1}). It is highly flammable. It is more soluble in water than O_2 or N_2 but less than CO_2.

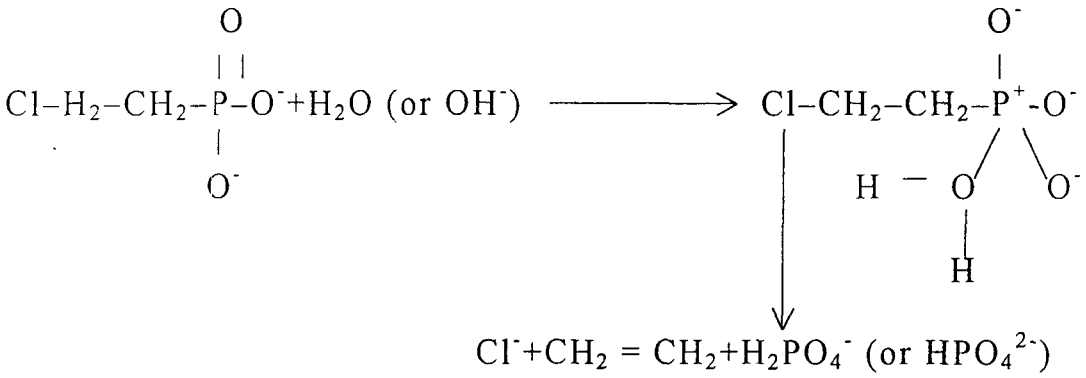


Structural formula of ethylene

Ethylene is the simplest olefin, which exists in the gaseous state under normal physiological conditions. Its effect on various physiological processes at different stages of plant growth and development has been documented (Yang and Hoffmann, 1984; Reid, 1987; Abeles *et al.*, 1992; Pua and Chi, 1993; Khan, 1996b and Khan *et al.*, 2000). Ethylene is known to exert its effects by altering gene expression both at transcriptional and post-transcriptional phases (Lincoln and Fischer, 1988). Dependant on the plant material and state of development, promoting or inhibiting effects of ethylene on internode growth has been observed (Raskin and Kende, 1984; Sisler and Yang, 1984). Physiological conditions like water stress or drought also promote the ethylene synthesis in plants (Tudela and Primo-Millo, 1992; Bergner and Teichmann, 1993; Michelozzi *et al.*, 1995).

Ethylene generating commercial chemical is ethephon or ethrel (2-chloroethyl phosphonic acid – $ClCH_2CH_2PO_3H_2$) (Warner and Leopold, 1969).

Ethrel is most important and versatile ethylene- releasing agent marketed and registered for more than 20 crops. It is a synthetic plant growth regulator that undergoes chemical biodegradation in cell cytoplasm at pH greater than 4.1 to release ethylene (Urwiller and Stutte, 1986; Kasele *et al.*, 1995).



2-chloroethyl phosphonic acid decomposes spontaneously in plant tissues to yield ethylene and phosphonic acid

The use of ethrel as a growth regulator has been shown for controlling growth and productivity of cereals and grain crops (Davis and Curry, 1991). Ethrel has also been found to impart tolerance against water stress and increasing the productivity of oilseed crop (Khan *et al.*, 2000). The other ethylene releasing compounds are etaelasil, holoethylesulfinic acids, 2-Hydroethylhydrazine (Palmer *et al.*, 1967; Dowllet and Kumanoto, 1972; Lurssen, 1982; Arteca, 1997).

Ethylene is a gaseous plant growth regulator involved in a diverse array of cellular developmental and stress related processes in plants. Prevention of ethylene accumulation in the atmosphere and inhibition of its effects by lowering the temperature and increasing the CO_2 concentration are wide spread storage practices. Silver ion also inhibits the ethylene action, acting at the receptor level (Veen, 1986), is a useful laboratory tool (Yang, 1987; Smalle *et al.*, 1997). Cobalt has been found to inhibit ethylene production and reversed

the effects of ethylene in soybean (Samimy, 1978). Mohan Ram and Rina (1982) reported the antagonistic properties of $AgNO_3$ and $COCl_2$ on ethylene and application of these compounds reverse the effects of ethylene in *Canabis sativa*. Mhatre *et al.* (1998) also reported the similar results. Silver thiosulphate is an inhibitor of ethylene action (Saniewske and Ludhika, 1989) and aminoethoxy vinylglycine inhibits the biosynthesis of ethylene (Child *et al.*, 1998; Kushad and Pooviah, 1984; Koritsas, 1988). Cyclopropenes and 2,5-norbornadiene have also been found to be effective antagonists of the ethylene response (Sisler and Yang, 1984; Sisler *et al.*, 1996a, b).

2.4 Crop Response to Ethylene Sources

2.4.1 Ethylene sources and growth parameters

2.4.1.1 Plant height

Growth regulators have been found to control plant height (Sauerbrey *et al.*, 1988; Guruprasad and Guruprasad, 1988; Dijkstra and Kuiper, 1989; Krishnamoorthy, 1993).

Depending on the plant material and state of development, promoting or inhibiting effects of ethylene on internode growth have been observed (Raskin and Kende, 1984; Sisler and Yang, 1984). Ethephon appreciably reduced the shoot length of sunflower plants and the internode elongation (Sauerbrey *et al.*, 1988). Slife and Earley (1970) applied ethrel to flowering soybean plants at 0.56 to 2.24 kg/ha rates and all the treatments caused a decrease in plant height. Foliar application of ethrel at a rate of 500, 1000 and 1500 µL/L reduced plant height in *Brassica napus* (Grewal *et al.*, 1993). Ethephon has been found to reduce plant height in barley (Bulman and Smith, 1993a; Sanvicente *et al.*, 1999), sunflower (Sauerbrey *et al.*, 1988), winter rape (Wareing and Philips, 1981), rice (Nafziger *et al.*, 1986), winter wheat (Van Sanford *et al.*, 1989), lupin (Ortuno *et al.*, 1993), linseed (Leitch and Kuat, 1999), radish (Vreugdenhil and Harro, 1989) and arabidopsis seedlings (Smalle *et al.*, 1997).

Contrarily, Jana and Kabir (1991) reported that application of ethrel to cauliflower cv. Dania significantly increased plant height at 300 µL/L concentration. However, growth was adversely affected at higher concentration.

2.4.1.2 Leaf number

Ramos *et al.* (1989) observed that ethephon application at tillering increased both number of ears per plant and per pot in spring barley (*Hordeum vulgare*). Ethephon was found to be beneficial for increasing the number of leaves per plant of onion (*Allium cepa* L.).

Researchers have observed controlling effects of ethrel on leaf expansion and production of plants with darker green foliage (Shanahan and Nielsen, 1987; Davis *et al.*, 1988; Butler *et al.*, 1989; Sairam *et al.*, 1989; Reddy *et al.*, 1996; Zhou and Xi, 1993; Kulkarni *et al.*, 1995; Zhou and Ye, 1996; Lee and Reid, 1997; Hussain *et al.*, 1999).

2.4.1.3 Leaf area

Ethylene has been shown to influence leaf expansion by suppressing cell enlargement rather than division (Kieber *et al.*, 1993; Rodriguez-Pousida *et al.*, 1993). Ethephon treatment reduced leaf area as compared to control plants in *Zea mays* (Kasele *et al.*, 1995). However, ethephon application promoted expansion of primary leaves of *Helianthus annus* while higher concentrations reduced it (Lee and Reid, 1997).

2.4.1.4 Leaf area index

Singh *et al.* (1987) working on soybean and Grewal and Kolar (1990) on mustard reported an increase in LAI in soybean by the application of ethrel. Flag leaf area index was greater in wheat treated with ethephon over control but plant leaf area index was not affected by ethephon application (Van Sanford *et al.*, 1989). Khan (1996b) and Khan *et al.* (2000) also reported an increase in leaf area index in response to ethrel spray in *Brassica juncea* L. under irrigated and non-irrigated conditions.

2.4.1.5 Dry matter

The plant growth regulator ethephon influenced the dry matter significantly in winter wheat (Nafziger *et al.*, 1986; Van Sanford *et al.*, 1989), in barley (Simmons *et al.*, 1988) and in mustard (Khan, 1996b; Khan *et al*, 2000). The dry weights of the main stem and root of ethrel treated mungbean plants were significantly higher (Panwar *et al.*, 1988). Contrary to these reports, Urwiller and Stutte (1986) noted decrease in dry weight of soybean plants due to ethephon treatment.

2.4.2 Ethylene sources and photosynthetic parameters

2.4.2.1 Chlorophyll

Favourable effects of growth regulators on chlorophyll content have been reported by number of workers. Ethrel at 500 µL/L concentration significantly increased the chlorophyll content in leaves of *Brassica napus*. However, at higher doses of ethrel (1000 and 1500 µL/L) showed detrimental effect (Grewal and Kolar, 1990; Grewal *et al.*, 1993). The exogenous application of ethylene in mustard (*Sinapis alba* L.) seedlings enhanced chlorophyll synthesis considerably (Buehler *et al.*, 1978). The ethylene producers (Camposan M, Ethephon and Dektrel) did not cause chlorosis and reduced green pigment level to a lesser degree in developing raspberry leaves.

2.4.2.2 Photosynthesis

Growth regulators may be employed to improve the physiological efficiency of plants by modifying the balance between photosynthesis and respiration (Arteca and Dong, 1981; Zerbe and Wild, 1981; Makeev *et al.*, 1992). The photosynthetic response of crop to the agro-chemicals varies from one extreme to the other. Increased rates of photosynthesis per unit leaf area have been observed after the application of growth regulators on different plant species (Child *et al.*, 1985; Liu *et al.*, 1993; Yang *et al.*, 1994). Plant growth regulators can affect photosynthetic CO_2 uptake either by effecting stomatal

aperture or by affecting the activity of photosynthetic enzymes (Foroutan-Pour *et al.*, 1997).

Foliar application of the ethephon to spring barley caused an increase in penultimate leaf photosynthetic rate (Pua and Chi, 1993). In one of the study of Subrahmanyam and Rathore (1992a), they found that ethrel application had no significant effect on photosynthesis in Indian mustard. However, photosynthesis in upper leaves and to a lesser extent in lower leaves was lowered by ethrel application. Exogenous application of ethrel has also been found to cause 12-18% reduction in photosynthesis (Subrahmanyam and Rathore, 1992a, b).

Studies conducted in the author's laboratory have shown that exogenous application of ethrel enhanced photosynthesis of *Brassica juncea* in irrigated and unirrigated conditions (Khan, 1996b; Khan, 1998; Khan *et al.*, 2000).

2.4.2.3 Photosynthetically active radiation

Photosynthetically active radiation (PAR) is a measure of radiation available for photosynthesis. It is well known that plants vary in response of the photosynthetic apparatus to radiations of different wavelengths within the canopy. Changes in radiation quality are largely due to the spectral properties of leaf pigments leading to a reduction in the red/far red ratio as light penetrates the canopy (Holmes, 1981; Ballare *et al.*, 1989; Guiamet *et al.*, 1989). In this respect there are several evidences that potentiate the chains of canopy change under the influence of growth regulators (Nickell, 1982), which bring about a desirable modifications in photosynthetically active radiation (Mathias *et al.*, 1989). Grewal and Kolar (1990) in their experiment on *Brassica napus* reported that application of ethrel (500, 1000 and 1500 µL/L) had negative impact on photosynthetically active radiation interception.

2.4.3 Ethylene sources and nutrient uptake

Plant growth regulators are known to influence transport and transport functions. Growth regulators have been affiliated with refinement of

assimilated translocation in established sink-source system (Thomas, 1986; Patrick and Steains, 1987). Desirable increase in the produce of field crops was probably due to alteration in the trends of assimilated distribution (Ado Quaye *et al.*, 1986). The allocation of newly fixed carbon in different metabolic products influenced the partitioning of carbon and growth activity of whole plant (Champigny, 1985).

Ethephon showed a strong effect on N-use efficiency and in particular on the role of N-uptake efficiency in winter wheat (Van Sanford *et al.*, 1989). Use of ethephon resulted in an increased N uptake in barley (Bulman and Smith, 1993a).

Contrarily, Dhakal and Erdi (1986) found that ethelene had no influence on K and Na levels neither at lower nor at higher concentrations in wheat.

In a field trial on mustard under irrigated conditions (Khan, 1998) and under non-irrigated conditions, Khan *et al.* (2000) reported that ethrel spray plants accumulated higher plant N and seed N content, and enhanced nitrogen harvest index and nitrogen yield merit (Khan, 1998). Under non-irrigated conditions ethrel-sprayed plants utilized N from the soil more efficiently and showed increased nitrogen harvest index and nitrogen yield merit.

2.4.4 Ethylene sources and yield parameters

Yield components like pod number, seeds per pod and seed specific weight not only depend on nutritional factor but also on hormonal concentration (Morgan, 1980; Crosby *et al.*, 1981; Carlson *et al.*, 1987; De-Bouille *et al.*, 1989; Paulpandi *et al.*, 1998).

2.4.4.1 Pod number

Foliar application of ethrel at a rate of 200 µL/L at flower- initiation stage improved the number of pods per plant in soybean (Singh *et al.*, 1987). Foliar spray of ethrel increased the number of mature pods per plant of peanut (*Arachis hypogea*) positively with sequential spray treatment over no spray in all the varieties (Saini *et al.*, 1984).

Urwiller and Stutte (1986) reported increased number of one-seeded pods in ethephon treated soybean plants. However, exogenous application of ethrel resulted in detrimental effect on pods per plant in *Brassica napus* (Grewal *et al.*, 1993). Results reported from authors' laboratory have confirmed the beneficial effects of ethrel on pod number of mustard (*Brassica juncea* L.) under irrigated (Khan, 1996b; 1998) and non-irrigated (Khan *et al.*, 2000) conditions.

2.4.4.2 Seed number

Pod number and seed number per pod are determined early after flowering (Pechan and Morgan, 1983) and though nutritional factors play an important role (Allen and Morgan, 1972; Tayo and Morgan, 1978), there is evidence that hormones may also operate on these yield components. Foliar application of ethrel at flowering and pegging stages increased number of seeds and size of seeds in groundnut (Mishra *et al.*, 1984).

2.4.4.3 1000 seed weight

Foliar application of ethrel increased 1000-grain weight in soybean (Singh *et al.*, 1987). Spray at flowering stage on Indian mustard also increased seed weight (Singh and Kumar, 1991). Ethephon increased 1000 seed weight of onion (*Allium cepa* L.) compared to control (Singh *et al.*, 1995). However, Grewal *et al.* (1993) observed that ethrel treatment resulted in detrimental effect on 1000 seed weight in *Brassica napus*, while Ramos *et al.* (1989) in barley (*Hordeum vulgare* L.) Khan *et al.* (2000) in mustard (*Brassica juncea* L.) Coffelt and Howell (1986) in peanut (*Arachis hypogea* L.) failed to observe any increase in 1000 seed weight in response to the foliar spray of ethrel.

2.4.4.4 Seed yield

Improvement in seed yield of different crops in response to growth substances was observed by Gopalkrishnan and Srinivasan (1975), Ries *et al.* (1977) and Menon and Srivastva (1984). The growth regulators have been found to engage in assimilate translocation towards reproductive parts of plants

(Pando and Srivastava, 1985; Khan *et al.*, 1996). Differential responses of ethephon were observed and several investigators reported about the beneficial effect on grain yields of winter wheat (Dahnous *et al.*, 1982; Leary and Oplinger, 1983; Wiersma *et al.*, 1986), while others claimed reduction with the use of ethephon (Nafziger *et al.*, 1986; Simmons *et al.*, 1988). Increase in seed yield of mustard in response to ethrel has been reported by Grewal *et al.* (1993), Khan (1996b; 1998), Singh and Kumar (1991) and Khan *et al.* (2000). Joshi *et al.* (1987) also reported increase in seed yield in groundnut (*Arachis hypogea* L.) when treated with ethrel. Foliar application of ethrel on cauliflower increased seed yield per plant at 300 mg/L while it was adversely affected at higher concentration (Jana and Kabir, 1991).

Ethephon treatment increased grain yield in corn (Kasele *et al.*, 1995) and barley (Bulman and Smith, 1993b). Contrarily, Slife and Earley (1970) applied ethrel to flowering soybean plants at 0.56 to 2.24 kg/ha, the treatments decreased yield of seed per hectare. Grewal *et al.* (1993) also observed substantial decrease in seed yield in *Brassica napus* with the use of 1000 and 1500 mg/L ethrel. Application of ethrel to foliage enhanced seed yield in *Brassica juncea* was reported by Khan *et al.* (2000). Early application of ethephon resulted in significant reduction in seed yield of linseed (Leitch and Kuat, 1999).

2.4.4.5 Biological yield

Biological yield was enhanced in ethylene treated mustard plants (Khan, 1996b; 1998; Khan *et al.*, 2000).

2.4.4.6 Harvest index

Seeds of groundnut (*Arachis hypogea* L.) were when treated with ethrel gave higher harvest index than water-soaked seeds (Joshi *et al.*, 1987), while Van Sanford *et al.* (1989) observed equivalent harvest index in both ethephon treated and control plants in winter wheat.

2.4.4.7 Oil yield

Khan (1996b) reported impressive increase in the oil yield of mustard in response to ethrel application.

2.4.5 Ethylene sources and quality parameters

2.4.5.1 Oil content

Exogenous application of ethrel at the rate of 250 mg/L reduced the essential oil content of peppermint and slightly increased the essential oil content of sage (*Sahia officinalis*) (El-Keltawi and Rodney, 1986). Farooqi and Sharma (1988) also reported an increase in oil content of *Rosa damascena* Mill by the application of 0.02 and 0.06% concentrations of ethrel. However, Khan (1996b) showed an increase in oil content in seeds of mustard. Grewal *et al.* (1993) in *B. napus* and Leitch and Kuat (1999) in linseed reported that ethrel application had no influence on the seed oil content of the plants.

2.4.5.2 Amino acid content

Sharma *et al.* (1982) reported that free amino acids contents increased during the pod development stage on application of ethrel on groundnut (*Arachis hypogea*).

2.4.5.3 Protein content

Plant growth regulators have been found to influence significantly the protein content in crop plants (Lurie *et al*, 1994; Liu *et al.*, 1993; Yang *et al.*, 1994; Kulkarni *et al.*, 1995). They have also been implicated in the control of protein allocation among plant organs and accumulation in developing cereal grains (Oritant and Yoshida, 1971).

Grain protein concentration increased (Morris *et al.*, 1989; Van Sanford *et al.*, 1989) or remained unaffected (Pearson *et al.*, 1989) by ethephon treatment. Soluble proteins increased with application of ethrel during initial stages of pod development but declined later in groundnut (*Arachis hypogea*) (Sharma *et al.*, 1982). Ethephon treatment increased protein content per grain and grain protein concentration in barley (Bulman and Smith, 1993b; Ma *et al.*,

1994b). Ethrel treatment has been found to increase protein content and efficient incorporation of amino acids into proteins in wheat (Sekhon and Singh, 1994).

2.4.5.4 Fatty acid

Ethephon has been reported to change the relative proportions of fatty acids, reducing the content of linolinic acid and increasing the oleic acid content (Leitch and Kuat, 1999).

Ethrel has also showed a promotive effect on conversion of lipid into sugars through glyoxylate cycle under water stress conditions in soybean seeds (Sharma *et al* , 1986).

2.5 Mineral Nutrition

Mineral nutrition includes the supply, absorption, utilization of essential nutrients for growth and yield of crop plants. This is not known with certainty when humans first incorporated organic substances, manures or wood ashes as fertilizers in the soil to stimulate plant growth. However, it is documented that as early as 2500 B.C., humans recognized the richness and fertility of alluvial soils in valleys of the Tigris and Euphrates rivers (Hewitt, 1963; Tisdale *et al.*, 1985).

Early progress in the development of understanding of soil fertility and nutrition concept was slow, although the Greeks and Romans made significant contributions in the years 800 to 200 B.C. (Marschner, 1986; Westerman and Tucker, 1987). It was only to the credit of Justus Von Leibig (1803-1873) that the scattered information concerning the importance of mineral nutrients for plant growth was collected and summarized the mineral nutrition of plants and was established as a scientific discipline (Marschner, 1983). Plants contain small amounts of about more than hundred elements but only 17 elements are known to be essential (Epstein, 1972; Fageria, 1984; Salisbury and Ross, 1994). The exclusive requirements of inorganic nutrients in higher plants basically distinguish them from man, animals and a number of microorganisms,

which additionally need organic compounds. Keeping in view the specific nature of the problem of thesis, the following pages deal with nutrient nitrogen, its properties and effect on oil crops with special emphasis on mustard.

2.5.1 Nitrogen

Nitrogen is one of the essential elements required for crop growth in higher concentrations than any other element. Nitrogen is the most important element for plants growth and productivity During seed germination hydrolysis products of storage proteins provide the nitrogen for initial growth. After the seedlings become photosynthetic, roots take up nitrogen from a soil, which is assimilated into amino acids and proteins in the vegetative tissues. The need for nitrogen increases steadily with multiplication and expansion of the developing vegetative organs and culminates during the reproductive stage with the synthesis of new seed storage proteins (Pate, 1980).

2.5.1.1 Acquisition and assimilation

Plant acquires nitrogen from two principal resources (1) the soil through commercial fertilizers, manure and/or mineralization of indigenous organic matter and (2) the atmosphere through symbiotic N_2 fixation (Vance, 1990). The availability of nitrogen in the rhizosphere regulates crop growth and development through optimum source and sink development during ontogeny. The uptake of N into plant roots is active energy requiring process (Oak and Hirel, 1985) making the roots a barrier to N uptake. The main sources of inorganic nitrogen for plant metabolism are nitrate and ammonium from the soil solution which act as substrates for reduction and subsequent incorporation into organic substances utilized by plant cell (Kleinhoffs and Warner, 1990; Lea *et al.*, 1990; Solomonson and Barber, 1990). Since ammonia is rapidly nitrified in soil (Schmidt, 1982), nitrate is a dominant form of mineral N available to higher plants except under acidic, cold and anaerobic soil conditions. The uptake and transport differ for nitrate and ammonium. The nitrate ions are transported to leaves largely as nitrates whereas ammonium

ions are assimilated in roots and transported as amino acids and amides to leaves (Arnozis and Findenegg, 1986; Shelp, 1987). Since NH_4^+ is toxic, it must be rapidly assimilated into non-toxic metabolites (Lea *et al.*, 1990). The type and concentrations of nitrogen in growth media exerts a considerable influence on growth and mineral composition of crop plants (Kurvitis and Kirkby, 1980; Gashaw and Mugwira, 1981; Ansari, 1990; Jeschke *et al.*, 1992). The form of N ion supplied to roots also influences the absorption and transport of other nutrients including cations K^+, Ca^{2+}, Mg^{2+} and Na^+ and anions SO_4^{2-}, PO_4^{3-} and Cl^- (Pilbean and Kirkby, 1992). As nitrate reduction is a process involving high-energy consumption, the direct utilization of ammonium could bring about a higher plant growth. However, more often the reverse is observed (Salsac *et al.*, 1987). Ammonium ions on entering the roots of plants are mediated by the GS-GOGAT system to form Gln and glutamate (Amanico and Santosh, 1992). The assimilation of NO_3^- by plants require the uptake of NO_3^-, reduction of NO_3^-, conservation of NO_3^- to NH_4^+, and the incorporation of NH_4^+ to organic compounds (Migge and Becker, 1996; Sivasankar and Oak, 1996).

Subsequently nitrogenous organic compounds such as amino acids are utilized through primary metabolic pathways for various aspects of the life cycle of plants (Richards *et al.*, 1994).

2.5.1.2 Nitrogen source

On a global scale terrestrial plants assimilate about 1.4 gigatons of nitrogen annually, approximately 90 to 95% of the total is from mineral nitrogen and the remaining from symbiotic dinitrogen fixation (Paul and Clark, 1988). Since dinitrogen fixation by living organisms (except for some symbiotic N_2 fixers) is generally quite limited (Tisdale and Nelson, 1967), therefore nitrogen is added to soils for most cropping system to achieve high yields. The two major nitrogen fertilizers in current use are ammonium

sulphate and urea with latter becoming more common specially in the regions of high rainfall and on heavy clay soils (Shand, 1996).

2.5.1.3 Mineralization

It is generally assumed that N fertility in soil in natural agro-ecosystems reaches at maximum equilibrium level under specific environmental conditions where organic matter inputs equal losses (Tate, 1992). However, the intervention of man in agro-ecosystem changed this equilibrium through effects of cultivation, which accelerates the oxidation of soil organic matter at or near the surface (Campbell and Souster, 1982). This results in loss of potentially mineralizable N fraction of organic matter that serves as a reservoir of N available to crops. Mineralization and immobilization processes occur simultaneously in wetland soils and depend on soil properties and environmental factors. Mineralization of organic N (native or added organic N sources) is the most important process in N nutrition of wetland crops (Broadbent, 1978). The mineralization of organic nitrogen compounds takes place in essentially three step-by-step reactions: aminization, ammonification and nitrification.

Aminization involves the breakdown of proteins in neutral and alkaline environments by bacteria, fungi and actinomycetes. One of the final stages in the decomposition of nitrogenous materials is the hydrolytic decomposition of proteins and release of amines and amino acids. This step is termed as aminization. The amines and amino acids so released are further utilized by the still other groups of heterotrophs including both aerobic and anaerobic microorganisms with the release of ammonical compounds. This step is termed ammonification.

Nitrification is generally referred to as biological oxidation of ammonium to nitrate via nitrite, affected by *Nitrosomanas* and *Nitrobacter* species of nitrifying bacteria (Sahrawat, 1978; 1980a, b, 1989; 1996). The nitrification process is generally controlled by ammonium availability

(Robertson, 1982). Additionally, soil pH and temperature regulate the rates of ammonification and nitrification (Francis, 1982; Schmidt, 1982; Gilmour, 1984). When nitrification inhibitors are used for controlling nitrification, the process is not arrested completely resulting in a preponderance of ammonium over nitrate in the soil which affects the persistence of applied N in the soil as well as plant N metabolism and N nutrition (Sahrawat and Keeney, 1984). Nitrification inhibitors also affect nitrogen transformation other than nitrification in soils, such as ammonium fixation and release, mineralization and immobilization, nitrous oxide production and ammonia volatilisation, which affect N persistence in the soil and its subsequent availability to plants (Sahrawat, 1989; 1996).

2.5.1.4 Nitrogen immobilization

Immobilization of nitrogen is the reverse of mineralization and occurs when large quantities of low-nitrogen crops residue such as cereal crop straw begin decomposing in soil. The high amounts of carbohydrate in such residues cause the population of soil microflora to build up quickly. As new cells are formed, nitrogen and other essential elements are used to build up protoplasm. This invariably leads to decrease in the level of inorganic nitrogen for crops.

2.5.1.5 Reasons for nitrogen deficiency

The utilization efficiency of soil applied N rarely exceeds 50 per cent in most cultivated crops (Greenwood, 1982). The remainder may be immobilized in soil as organic matter or it may be lost from soil causing potentially economic and environmental consequences. Leaching, surface runoff, ammonia volatilisation and denitrification comprise the major ways for N-loss, the actual relevance of these depends on the climatic and soil conditions (Vlek and Byrnes, 1986).

Nitrogen leaching takes place mainly from nitrate but also from urea molecules. As nitrate is not absorbed to the soil complex, it tends to move downward at the same rate as water. The amount of nitrate leaching depends on

rainfall rate and soil conditions (especially texture and organic matter content) Except in few situations, the loss of N through leaching has been found non-significant (Katyal *et al.*, 1985). In general, the risk of surface transport of N is directly proportional to the amount of N applied as fertilizer. The nitrogen losses caused by leaching due to excess of rainfall can be very high. Losses were measured upto 90 kg/ha/year and were certainly one of the expectations for the low nitrogen use efficiency in cereal crops in Mediterranean regions Reducing the risk of leaching losses would increase nitrogen use efficiency and reduce nitrogen fertilization (Carvalho and Basch, 1996)

2.5.1.6 Denitrification loss

Denitrification is the process by which nitrogenous oxides principally NO_3^- and NO_2^- are reduced to dinitrogen gases. The process is generally considered to be carried out by facultative anaerobes – organisms that normally use oxygen for respiration but in its absence use N-oxides as electron acceptors (Groffman, 1995). There is evidence that some organisms can simultaneously respire O_2 and NO_3^- in what has been termed "anaerobic denitrification" (Lloyd, 1993, Robertson and Kuenen, 1991).

Nitrification in oxidized soil zones and flood water converts ammonical N form by ammonification and hydrolysis of urea into NO_3-N. Thus, NO_3-N can thereafter move to reduce soil zone where it is readily denitrified to dinitrogen and nitrous oxide (Reddy and Patrick, 1986). Denitrification in waste treatments can remove excess nitrate, decrease nitrate contamination of ground waters, affects atmospheric composition through the production and consumption of N_2O and thus has impact on climate. It can produce toxic intermediates NO and NO_2^- the latter can lead to carcinogenic nitrosamines (Tiedje, 1988).

2.5.1.7 Gaseous loss of nitrogen

The increase in use of N fertilizer worldwide coupled with a trend towards more extensive use of anhydrous ammonia and urea has increased the

potential for NH_3 loss from fertilizers (Sharpe and Harper, 1995). Urea has become the most used N fertilizer in the world, accounting for approximately 40% of the total synthesized N supply. Its market share is increasing because it is the least expensive form of solid N fertilizer available and its high N content (46%) offers transportation advantages (Byrnes and Freney, 1995). Although urea has cost advantage over other products, but disadvantage with it is that in the considerable loss of N occurs if the urea is not incorporated in the soil soon after application. The loss occurs through ammonia volatilisation after the urea is hydrolysed at the soil surface by reaction with the enzyme urease (Mulvaney and Bremner, 1981; Ladd and Jackson, 1982). Gaseous loss of urea fertilizer N as NH_3 is of particular concern because it can exceed 50% of the applied amount (Terman, 1979). Soil factors that affect volatilisation include cation exchange capacity, soil pH and moisture. Reducing NH_3 loss has been found to be associated with a high cation exchange capacity i.e. there exists a negative correlation between CEC and NH_3 loss (Lyster *et al.*, 1980; Ryan *et al.*, 1981; Ferguson *et al.*, 1984; O'Toole *et al.*, 1985). Ammonia losses increase with higher soil pH because of increased dissociation of NH_4 to NH_3, thus increasing the potential for volatilisation (Ryan *et al.*, 1981; Chai and Hou, 1975; More and Varade, 1978). Environmental factors, which affect NH_3 volatilisation, include air, temperature, wind speed, rainfall and atmospheric NH_3 concentration (Denmead *et al.*, 1982; Freney *et al.*, 1983).

2.5.1.8 Control of mineral fertilizer N loss in soil

Nitrogen losses can be controlled either agrotechnically or chemically. The goal is to conserve mineral fertilizer N to a form, which is not sensitive to leaching or volatilisation. In this respect application of required amount of fertilizer to the specific requirement of the crop is recommended. This optimum nitrogen content of a plant species is the amount sufficient to maintain maximum growth rate. Any amount more than optimum nitrogen does not increase the growth rate but increases the chances of loss. Deep placement of

urea-based fertilizers can minimize volatilisation and immobilization losses by reducing fertilizer contact with dead and decaying plant residue (Doran, 1980; Jannson and Persson, 1982). When compared with surface broadcast application, deep placement has been shown to increase fertilizer N-use efficiency to about 20% (Soper *et al.*, 1971; Towes and Soper, 1978; Tomar and Soper, 1981).

2.5.1.9 *Consequences of nitrogen deficiency*

Nitrogen is considered one of the major limiting nutrients in plant growth and development (Richards *et al.*, 1994). The deficiency of the essential nutrients results in a significant change in the development of various organs and the plant as a whole (Mishra *et al.*, 1985). Nitrogen deficiency not only affects cell number but also size in plant species of various crops. Nitrogen stress affected leaf size through both cell production and cell expansion. Nitrogen deficits altered source-sink relations, strengthened root growth and reduced growth of whole plant and dry matter accumulation. Nitrogen metabolism and photosynthesis were unpaired, plant nitrate content and all free amino acids and proteins decreased. Nitrogen deficiency reduced plant height, leaf area, leaf number, dry matter, harvest index and also reduced yield by reducing the number of seeds per plant and by decreasing seed weight. Chweya (1990) reported that nitrogen deficiency leads to poor vegetative growth and therefore leads to accumulation of glucosinolates in the leaves of kale plant. In general, limited N supply results in plant with a reduced shoot/root dry weight ratio (Ingestad, 1980; Kerr *et al.*, 1986). The plants with no nitrogen are usually are pale and yellow in colour, which would signal to a grower to apply more N (Paparozzi *et al.*, 1994). Nitrogen used in chlorophyll synthesis aids in visual diagnosis of N deficiency by influencing the plant colour, as total chlorophyll reduces in low nitrogen supply (Longstreth and Nobel, 1980). Upon decrease in nitrogen supply the rate of photosynthesis per unit leaf area decreased whereas the photosynthetic nitrogen use efficiency increased (Van der Werf *et al.*,

1993). Uhart and Andrade (1995a, b) reported that nitrogen deficiency reduced leaf area duration, leaf area index, aerial dry matter, crop growth rate, intercepted photosynthetic active radiation and water use efficiency. Results of similar nature on N deficiency were observed by number of researchers including Novoa and Loomis (1981), Lemcoff and Loomis (1986), Mai *et al.* (1987), Sinclair and Horie (1989) and Connor *et al.* (1993) and Dodd (2001).

2.6 Crop Response to Nitrogen

There is a great pressure to achieve breakthrough in human nutrition by introducing new foods into diets by developing new cultivars of staple crops that have high protein contents and at the same time produce high yields. The probability of accomplishing either goal on sustained basis is still eluding. But strategic use of fertilizers and manures may change the scenario.

2.6.1 Nitrogen and growth parameters

2.6.1.1 Plant height

Nitrogen promotes growth of stem by way of better cell division and their elongation (Awasthi and Surajbhan, 1994; Pradhan *et al.*, 1994). Each successive increase in N level from 0 to 8 kg/ha significantly increased the growth characters in Indian mustard (Sharma *et al.*, 1994), while increasing nitrogen levels resulted in significant increase in plant height under rainfed conditions in Indian mustard. Application of nitrogen showed significant positive effect on mean plant height of *B. napus* cv. Canola and *B. compestris* L. cv. Rapeseed (Al-Jaloud *et al.*, 1996). At both vegetative and reproductive stages, N doses showed a linear increase in plant height of fennel (*Foeniculum vulgare* Mill.) with 90 kg/ha giving maximum height increase at both stages (Afridi *et al.*, 1983). Nitrogen enhanced vegetative growth of plants has also been reported by Chweya (1990) and Paparozzi *et al.* (1994). The height of *Brassica juncea* increased significantly with increasing N from 0 to 90 kg/ha at every growth stage (Tomar *et al.*, 1996). Khanpara *et al.* (1993) have also reported the similar results.

2.6.1.2 Leaf number

Nitrogen supply can be very limiting to productivity mainly through its effects on number and size of leaves and roots and on the photosynthetic rate of single leaf. Increase in N levels in rainfed cotton significantly increased the number of leaves (Perumal, 1999). Application of nitrogen at a rate of 30 kg/ha increased number of leaves of mustard (*B. juncea*) (Prassad and Shukla, 1993).

2.6.1.3 Leaf area

The essential role of nitrogen on leaf growth has long been recognized. Nitrogen fertilization results in increased leaf area (Pregtizer *et al.*, 1990; Ericsson *et al.*, 1992; Liu and Dickman, 1992; Heilman and Fu-Guang, 1993; 1994; Perumal, 1999). Leaf area can be viewed as the result of the rate and duration of leaf expansion. Leaf expansion rate is very responsive to nitrogen supply both under controlled and field conditions (Steer *et al.*, 1984; 1986; Connor *et al.*, 1993; Dodd, 2001). Rood and Major (1984) showed leaf growth to be particularly responsive to large amounts of N in Brassica crops. Nitrogen fertilizer application increased per unit leaf area of oil seed rape (*Brassica napus* L.) (Asare and Scarisbrick, 1995). Increased allocation of dry matter to shoot was reflected in increased rates of leaf expansion and elongation in high N-plants (Huber *et al.*, 1989). Leaf area expansion was higher in wheat cultivar Oligoculum when nitrogen was applied (Madhulety and Prakash, 1988). Certainly, it is clear that if N supply rate to the crop for new leaf growth is restricted, the amount of leaf area produced is proportionally restricted (Nova and Loomis, 1981; Lemcoff and Loomis, 1986; Prasad and Shukla, 1993).

2.6.1.4 Leaf area index

Increasing level of N increased the leaf area index progressively. Higher leaf area index helps the crop to put forth high production (Sarkar *et al.*, 1999).

Nitrogen application to *Brassica juncea* significantly increased LAI and was considerably higher at all stages at 100 kg N/ha than 50 kg N/ha while in absence of N, leaf area index was lesser (Grewal and Kolar, 1990). Khan and

Agarwal (1988) reported that leaf area index increased with increasing N rates in the range of 0-80 kg/ha but did not show further enhancement with 120 kg N/ha in mustard (*Brassica juncea*). Leaf area index increased with increase in nitrogen level, however there was no significant increase after 40 kg N/ha in groundnut (Patra *et al.*, 1995). Perumal (1999) also reported that leaf area index increased significantly with increasing N levels on rainfed grown cotton. Pradhan *et al. (1994) and Dey et al. (1989a, b) also reported similar results for* leaf area index in response to nitrogen.

2.6.1.5 Dry matter

Dry matter in general increased significantly with N doses applied (Cajuste *et al.*, 1996; Polley *et al.*, 1999). Nitrogen application increased biomass production favourably from an early stage and was significantly higher with 80 kg N/ha at advance stage of growth due to vigorous growth in sunflower (*Helianthus annus* L.) (Sarkar *et al.*, 1999). Dry matter production in groundnut increased at all growth stages with increase in nitrogen level, however beyond 40 kg/ha no significant increase took place (Patra *et al.*, 1995). Sawan *et al.* (1998) reported that seedling fresh and dry weight increased with increasing N rate (161 kg N/ha) in cotton plants. Increase in N rate, increased dry matter production under water scarce condition (Vyas *et al.*, 1995). Dry matter production has also been reported to increase with the application of nitrogen (Dubey and Khan, 1993). Khan and Agarwal (1988) reported that dry matter accumulation per plant increased with increasing N rates in the range of 0-80 kg/ha in mustard. However, it does not increase further with 120 kg N/ha. Application of 60 kg N/ha significantly increased dry matter in Indian rape (*Brassica campestris* L.) genotypes (Satyavan *et al.*, 1999).

Nitrogen produced linear increase in fresh weight and dry weight of fennel (*Foeniculum vulgare* Mill.). Nitrogen fertilized plants of linseed (*Linum usitatissmum* L.) produced appreciably more dry matter throughout the growing

season than unfertilised plants (Singh and Mishra, 1994) Raghuvanshi *et al.* (1987) and Singh and Saran (1987) reported the similar results in linseed. Dry matter of maize (Mishra and Srivastava, 1985; Huber *et al.*, 1989) wheat (Madhulety and Prakash, 1988), oilseed rape (Asare and Scarisbrick, 1995; McGrath and Zhao, 1996), poinsettia (Paparozzi *et al.*, 1994), *B. juncea* (Tomer *et al.*, 1996, Khanpara *et al*, 1993; Samiullah *et al.*, 1990), castor (Bheemaiah *et al*, 1998) significantly increased with increase in the rates of N application Nitrogen progressively and significantly increased the dry matter production of rainfed as well as irrigated sesame (*Sesamum indicum* L) (Vyas *et al.*, 1999)

2.6.1.6 Crop growth rate

Nitrogen application increased crop growth rate of castor (Bheemaiah *et al*, 1998) Pradhan *et al* (1994) also reported increased crop growth rate by N application. Increasing level of nitrogen from 0 to 60 kg/ha increased the crop growth rate of barley genotypes under moisture stress conditions (Awasthi and Surajbhan, 1994) Post flowering application of urea solution significantly and positively influenced crop growth rate of groundnut (Reddy *et al.*, 1991). Patra *et al* (1995) also reported increase in crop growth rate with increase in nitrogen level, however there was no significant increase after 40 kg/ha in groundnut. The crop fertilized with 80 kg N/ha showed higher crop growth rate values over 40 kg N/ha due to potential role of N in metabolic activities and on vegetative growth of *Helianthus annus* plants (Sarkar *et al.*, 1999). Khan and Agrawal (1988) reported that crop growth rate increased with increase in N rates in mustard (*B. juncea*) but did not further increase with 120 kg N/ha.

2.6.1.7 Leaf area duration

Leaf area duration increased with increasing N rates in the range of 0-80 kg/ha but did not increased further with 120 kg N/ha in mustard (Khan and Agarwal, 1988) Patra *et al* (1995) also reported increase in leaf area duration with increase in nitrogen level.

2.6.1.8 Relative growth rate

Nitrogen application showed progressively higher relative growth rate than respective level of N upto 45-60 days but at later stages the increase was inconsistent and even decreased in certain cases with increase in N level in sunflower (*Helianthus annus* L.) (Sarkar *et al.*, 1999).

2.6.1.9 Net assimilation rate

Glimskar and Ericsson (1999) reported that decrease in net assimilation rate at nitrogen limitation was very small but net assimilation rate was slightly positively correlated with relative growth rate while the plant nitrogen content was significantly and positively correlated with relative growth rate. Increasing level of N upto 80 kg/ha increased net assimilation rate mainly due to increase in crop growth rate and relative growth rate in sunflower (Sarkar *et al.*, 1999).

2.6.2 Nitrogen and photosynthetic parameters

2.6.2.1 Chlorophyll

The role of nitrogen in the build up of chlorophyll molecules has long been recognized (Evans and Terrshima, 1988; Sage *et al.*, 1990; Liu and Dickman, 1992). Chlorophyll content of fresh leaves, a measure of photosynthetic activity increased with N application in *Brassica juncea* (Grewal and Kolar, 1990). An increase in N rate increased levels of total chlorophyll in Indian mustard grown under different level of stored moisture (Vyas *et al.*, 1995). Leaf chlorophyll content in mustard (*Brassica juncea*) increased upto 90 kg N/ha and was highest with three irrigations (Chouhan *et al.*, 1994). Grewal *et al.* (1993) reported that the chlorophyll content in fresh leaves of *Brassica napus* L. increased with an increase in N upto 100 kg/ha.

2.6.2.2 Photosynthesis

Nitrogen has a profound role in metabolic processes resulting in increasing production of photosynthates (Dhoble, 1998). Nitrogen supply can affect plant growth and productivity by altering both leaf area and

photosynthetic capacity (Bolton and Brown, 1980; Novoa and Loomis, 1981; Wong *et al.*, 1985; Sinclair, 1990).

Photosynthesis in the leaves of soybean increased with nitrate supply (Rigaud, 1981; Chi *et al.*, 1983). The increase in the rate of photosynthesis has been noted to 43% higher than that of untreated plant (Varade *et al.*, 1995). CO_2 assimilation is generally higher at higher N concentrations (Sage *et al.*, 1987; Evans, 1989), as the nitrogen is involved in the enzymes of the photosynthetic carbon reduction cycle and thylakoid proteins constitute the majority of leaf nitrogen (Evans and Seemann, 1989). Leaves with high nitrogen content can utilize high photon flux densities more effectively for photosynthesis than those with low nitrogen content (Field, 1983; DeJong and Doyle, 1985). With the increase in N supply there was increase in photosynthesis due to increased leaf size in groundnut (Patra *et al.*, 1995). Increasing N from 0 to 50 and from 50 to 100 kg/ha helped the crop canopy of *Brassica juncea* to trap more radiation for photosynthesis (Grewal and Kolar, 1990). Grewal *et al.* (1993) also reported that interception of PAR by the crop canopy of *Brassica napus* improved significantly with increase in N rates from 0 to 100 kg/ha.

2.6.3 Nitrogen and nutrient uptake

The type and concentration of nitrogen in growth media exert a considerable influence not only on the growth and mineral composition of crop plants (Kurvitis and Kirkby, 1980; Gashaw and Mugwira, 1981; Ansari, 1990; Jeschke *et al.*, 1992) but also affect the relative uptake of cations and anions (Kirkby, 1981; Lovatt, 1986). Increasing levels of nitrogen increased the uptake of N regularly irrespective of growth stage in linseed (*Linum usitatissimum* L.) (Singh and Mishra, 1994). Reddy and Reddy (1986) have also reported the similar results. The concentration of some nutrients like phosphorus, potassium and calcium in certain organs of the oilseed rape plant has been found to be influenced by the nitrogen nutrient e.g. leaf P

concentration in oilseed rape was not influenced by N supply but P concentrations in the root, stem and axillary branches increased in response to higher N nutrition (Kullimann *et al.*, 1989). Similar observations were reported by Corntortill and Steele (1981) and Amoruwa *et al.* (1987) in field grown maize.

Applied N affected amount of leaf N content such that less N was present in leaves if no N was applied in poinsettia (*Euphorbia pulcheinma* wild) (Paparozzi *et al.*, 1994). The content of organic nitrogen in leaves of maize seedlings increased with increase in the supply of inorganic nitrogen in the nutrient medium (Mishra and Srivastava, 1985). Muchow and Sinclair (1994) also reported that canopy leaf N increased in response to increased N fertilizer treatments in maize (*Zea mays* L.).

Nitrogen application increased its uptake and the effect was more pronounced under irrigated conditions in sesame (Vyas *et al.*, 1999). Pinkerton (1991) observed that critical P concentration depended on plant age and N in oilseed rape and Indian mustard. Bulman and Smith (1993a) found that higher rates of nitrogen fertilizer increased the plant N concentration and total plant accumulation in spring barley N and P uptake increased with increase in N rate in Indian mustard (Vyas *et al.*, 1995). N, P and K uptake increased with N rate in mustard varieties (*Brassica juncea* L. Czern & Coss.) (Tripathi and Singh, 1992). Compared with unfertilized control uptake of N, P, K, Ca and Mg increased with increase in N fertilizer rate in mustard. Application of 60 kg N/ha significantly increased N uptake by seed, whereas uptake of N by stalk as well as total increase was upto 90 kg/ha of N applied to Indian rape (*B. compestris* L.) genotypes (Satyavan *et al.*, 1999). Increase in the rates of N uptake with increased nitrogen application in rapeseed mustard has also been observed by Patil and Bhargava (1987), Kumar *et al.* (1989), Dubey and Khan (1993).

2.6.4 Nitrogen and yield parameters

2.6.4.1 Pod number

Nitrogen application increased mean number of pods per plant in oilseed rape (*Brassica napus* L.) under drought conditions (Asare and Scarisbrick, 1995). The number of pods per plant in Indian mustard increased by nitrogen application significantly upto 80 kg N/ha under rainfed conditions (Thakuria and Gogoi, 1996). Increase in the number of siliqua per plant with increasing levels of N upto 60 kg/ha in Indian mustard (*Brassica juncea*) has also been reported by Rathore and Manohar (1989), Khanpara *et al.* (1993), while Tomar *et al.* (1996) and Dubey *et al.* (1993) reported the increase upto 90 kg/ha. Grewal and Kolar (1990) observed that the number of pods per plant in *B. juncea* increased significantly with increase in N from 0 to 100 kg/ha. Post flowering application of urea solution significantly and positively influenced pods per plant of groundnut (Patra *et al.*, 1995).

2.6.4.2 Seed number

Seeds per siliquae in *Brassica juncea* significantly increased due to each increment in level of N from 0 to 90 kg/ha (Tomar *et al.*, 1996) while Khanpara *et al.* (1993) reported the increase in seeds per siliquae with increasing level of N upto 60 kg/ha in Indian mustard.

Increase in seeds per siliquae with increase in application of N fertilizers has also been reported in *B. juncea* by Reddy and Sinha (1988), Rathore and Manohar (1989), Dubey *et al.* (1993). The number of seeds per pod of *B. juncea* increased significantly with the increase in N from 0 to 100 kg/ha (Grewal and Kolar, 1990). Thakuria and Gogoi (1996) reported that nitrogen application increased seeds/siliquae upto 80 kg N/ha under rainfed conditions in Indian mustard. Contrarily, Asare and Scarisbrick (1995) could not find any significant effect of nitrogen application on number of seeds per pod in *Brassica napus* under drought conditions.

2.6.4.3 1000 seed weight

Seed weight of *B. napus* was increased by nitrogen (Asare and Scarisbrick, 1995). 1000-seed weight in Indian mustard (*Brassica juncea*) increased with increasing levels of applied N upto 60 kg/ha (Khanpara *et al.*, 1993). Similar results were also recorded by Reddy and Sinha (1988), Rathore and Manohar (1989). Patra *et al.*, (1995) reported that 1000-kernel weight significantly and positively increased by post-flowering application of urea solution to groundnut.

Tomar *et al.* (1996) reported that 1000-seed weight was significantly increased due to each increment in level of N from 0 to 90 kg/ha in *Brassica juncea.* Seed weight in *B. juncea* increased significantly with increase in N level from 0 to 50 kg/ha but decreased with the further increase of N from 50 to 100 kg/ha (Grewal and Kolar, 1990). Thakuria and Gogoi (1996) also reported significant increase in 1000-seed weight in Indian mustard. Increase in 1000-seed weight in Indian mustard under rainfed conditions with increase in nitrogen upto 60 kg N/ha has also been reported by Singh and Kumar (1991). Contrary to above results, Chaudhary *et al.* (1992) reported that 1000-seed weight was unaffected by N application. Weight per seed was not affected by N treatment applied either through soil or to the peduncle in barley (Foroutan-Pour *et al.*, 1997; Ma and Smith, 1992; Ma *et al.*, 1994a).

2.6.4.4 Seed yield

For agricultural crops yield has been found increasing with increase in nitrogen fertilizer application (Bandel *et al.*, 1980; Howard and Tyler, 1989; Stecker *et al.*, 1993). Reddy (1983) noted that higher fertilizer rate increased seed yield of linseed. Application of 80 kg N/ha gave significantly higher seed yield in sunflower over no nitrogen application (Sarkar *et al.*, 1999). Increase in seed yield of sunflower has also been reported by Zaman and Chaudhari (1998), Dhoble (1998) and Singh and Bansal (1999). Awasthi and Surajbhan (1994) reported that at 60 kg N/ha, growth and yield attributes were found

maximum over other levels of nitrogen in barley. Increase in the seed yield of cotton due to applied nitrogen has been reported by Sawan *et al.* (1998) and Perumal (1999). Nitrogen had little effect on the grain yield of triticale below 90 kg N/ha, but increased with higher levels of nitrogen and declined at 180 kg N/ha (Naylor and Stephan, 1993). Increase in the seed yield of *Brassica juncea* with the increase in applied nitrogen has been reported by Reddy and Sinha (1988), Rathore and Manohar (1989), Grewal and Kolar (1990), Prasad and Shukla (1992), Khanpara *et al.* (1993), Sharma (1994), Ghosh *et al.* (1995) and Thakuria and Gogoi (1996). A similar effect on *Brassica napus* has been reported by Gendy and Marquard (1989), Grewal *et al.* (1993) and Asare Scarisbrick (1995). Application of nitrogen showed significant positive effect on mean seed yield of *Brassica napus* cv. Canola and *B. campestris* L. cv. rapessed (Al-Jaloud *et al.*, 1996). Bheemaiah *et al.* (1998) also reported increase in seed yield of castor with increased nitrogen application.

2.6.4.5 Harvest index

Application of 40 kg N/ha significantly increased harvest index in mustard but was reduced at 60 kg N/ha (Ghosh *et al.*, 1995). Dey *et al.* (1989b) also reported that harvest index increased upto 60 kg N/ha in rice (*Oryza sativa*).

2.6.4.6 Oil yield

A linear increase in oil yield was observed with increasing N application from 0 to 100 kg N/ha (Arthamwar *et al.*, 1996). Application of 40 kg N/ha increased seed yield significantly but was reduced at 60 kg N/ha in rainfed rapeseed (Ghosh *et al.*, 1995). With the application of nitrogen, oil yield increased in different *Brassica* genotypes (Kumar *et al.*, 1995). Singh *et al.* (1994) reported that oil yield of *Brassica* species increased upto 80 kg N/ha. Rana *et al.* (1991) reported that the oil yield in *Brassica juncea* increased with irrigation and N rate. Increase in N rates in the range of 90-180 kg/ha increased

oil yields compared with lower N rates or no N in mustard (Rathore and Manohar, 1989)

2.7.5 Nitrogen and quality parameters

2.7.5.1 Oil content

Smith *et al* (1988) described an inverse linear response between oil content and seed N concentration in *Brassica napus*. Nitrogen application affected adversely the seed oil content of oilseed rape (*B napus* L.) (Asare and Scarisbrick, 1995; Pinkerton, 1991, Gendy and Marquard, 1989) while Grewal *et al* (1993) reported that oil content of seeds in *B napus* significantly increased with the application of 50 kg N/ha over no nitrogen application However, increasing the dose of N from 50 to 100 kg/ha resulted in a decline in the oil content of seeds. Oil content of rainfed mustard increased significantly upto 40 kg N/ha and there was reduction in oil content at 60 kg N/ha (Ghosh *et al* , 1995) Oil percentage of *Brassica juncea* seeds increased significantly with the application of 50 kg N/ha but application of 100 kg N/ha resulted in significant decline (Grewal and Kolar, 1990). Increase in the oil content with N application has also been reported by Ghatak *et al.* (1992), Arora *et al.* (1994), Chouhan *et al* (1994) and Patra *et al* (1995). Application of nitrogen showed significant positive effect on mean oil content of *Brassica napus* L. cv Canola and *Brassica campestris* L cv. Rapeseed (Al-Jaloud *et al* , 1996). However, Satyavan *et al* (1999) reported that N application at all rates decreased oil content of Indian rape (*B compestris* L) genotypes when compared with control The adverse effect of nitrogen on oil content in different Brassica genotypes has been reported by Rana *et al.* (1991), Tripathi and Singh (1992), Dubey and Khan (1993), Singh *et al.* (1994), Shukla and Kumar (1994), Kumar *et al.* (1995) and Tomar *et al.* (1997) While Rathore and Manohar (1989), Saran and Giri (1990) and Chaudhary *et al.* (1992) reported that seed oil content in *Brassica juncea* was unaffected by the applied nitrogen rate.

2.7.5.2 Aminoacids

As nitrogen application to triticale increased over the range of 0-80 kg/ha there was a significant decrease in the proportions of alanine and glycine. However, significant increase in histidine and phenylalanine was observed. Serine showed no significant response to the supply of nitrogen. Other amino acids generally showed a curvilinear response to proportion of nitrogen in the grain protein (Naylor and Stephen, 1993). An increase in amino acids with a simultaneous decrease in carbohydrate synthesis has been reported when ammonium (Platt *et al.*, 1977) or nitrate (VanQuy *et al.*, 1991; Champigny *et al.*, 1992) was supplied. Vyas *et al* (1995) reported that as N rate increased, the free amino acids increased in Indian mustard despite low water potential.

2.7.5.3 Protein content

Under field conditions grain protein concentration increased as soil nitrogen fertility increases in barley (Bulman and Smith, 1993b). Increasing the amount of nitrogen applied usually caused an increase in the deposition of storage proteins (which has higher contents of glutamic acid and proline) and thereby reducing the proportion of proteins typical of the embryo and aleurone layer (e.g. aspartic acid, arginine and lysine) in triticale (Naylor and Stephen, 1993). Patra *et al.* (1995) reported that with the increase in N supply, the quantity of soluble proteins increased in groundnut. Protein content of leaves in maize seedlings increased with the increase in the supply of inorganic nitrogen in the nutrient medium (Mishra and Srivastava, 1985). Nitrogen levels significantly affected the protein content with each increase in the dose of N upto 90 kg/ha in Indian mustard (*Brassica juncea*). As the N supply increased the formation of protein also increased (Dubey *et al.*, 1994). Tandon (1986) and Singh and Saran (1987) also found similar results. Asare and Scarisbrick (1995) also reported inverse relationship between applied nitrogen and seed protein of *Brassica napus* L. seeds. However, Gendy and Marquard (1989) reported that protein content of *Brassica napus* L. seeds increased with increase

in nitrogen supply. Application of nitrogen showed significant positive effect on mean protein content of *Brassica napus* L. cv. Canola and *Brassica campestris* L. cv. Rapeseed under irrigated conditions (Al-Jaloud *et al.*, 1996). Increase in the protein content in rapeseed mustard with increasing rate of nitrogen applied has also been reported by Patil and Bhargava (1987) and Satyavan *et al.* (1999).

2.7.5.4 Fatty acids and glucosinolate

Seed glucosinolate content responded variably to use of N fertilizer application. It increased significantly with N application in some cultivars but not in other cultivars of *Brassica napus* L. (Asare and Scarisbrick, 1995).

In contrast, Ramans (1989) reported no significant effect of nitrogen fertilizer application on glucosinolate content in *Brassica napus*. The allyl-iso-thiocyanate content increased in the oil of Indian mustard (*Brassica juncea* L. Czern & Coss.) with higher N rates (Narang *et al.*, 1985). Seed allyl-iso-thiocyanate content was increased by N application in mustard (Arora *et al.*, 1994). Thakral *et al.* (1996) reported that glucosinolate contents of *Brassica carinata* and *Brassica napus* increased with increase in N fertilizer. While Singh *et al.* (1994) reported hat the sinigrin glucosinolate content of *Brassica* species increased upto 20 kg N/ha.

Fatty acid composition in seeds of Brassica species was affected significantly with increase in levels of N fertility (Thakral *et al.*, 1995). Allyl-iso-thiocyanate and fatty acid contents were increased by applied N (0-90 kg N/ha) in *Brassica juncea*. Application of nitrogen increased the erucic acid content but decreased linolenic acid linoleic acid contents in *Brassica juncea*. Application of N on white mustard increased percentage of oleic acid but decreased linolenic acid in the oil. Total saturated acids increased with N. Contrarily, Gendy and Marquard (1989) reported that the pattern of fatty acids in the oil of *Brassica napus* L. was not influenced by nitrogen level.

2.7.5.5 Acidity of oil/iodine number

The iodine value of *Brassica* species oil increased upto 20 kg N/ha (Singh *et al.*, 1994). Arora *et al.* (1994) also reported that iodine value of mustard oil was increased by N application. Iodine value of *Brassica carinata* and *Brassica napus* oil increased with increase in N (Thakral *et al.*, 1996). Application of nitrogen at a rate of 0-90 kg/ha increased iodine value of *Brassica juncea* oil. Narang *et al.* (1985) also reported that iodine number of *Brassica juncea* oil increased with higher N rates.

2.8 Crop Response to Interaction between Ethylene Sources and Nitrogen

Plant hormones and inorganic nutrients share a common physiological function i.e. both of these growth factors influence the growth and development of plants. Plant growth regulators have been found to be engaged in enhancing growth and productivity of crop plants. There are many instances which suggest that growth regulators and nutrients can interact in a variety of ways. Deficient and toxic levels of nutrients can affect the concentration of specific hormones, and in turn, hormones have the capacity to direct the translocation and accumulation of nutrients in plants (Kuiper, 1988; Kuiper *et al.*, 1989). Actually the nutrient status of a plant influences its metabolism and growth and can affect the synthesis and distribution of growth substances (Haru *et al.*, 1982; Green, 1983). Considering the complex interactions of plant hormones and multiplicity of plant functions they control, the impact on nutrients on hormones is an important issue (Whenham *et al.*, 1989; Thoresteinsen and Eliasson, 1990; Arshad and Frankenberger, 1991; Cao *et al.*, 1993).

In the following pages, attempt has been made to cover aspects of interactions of nutrients with ethylene sources application.

2.8.1 Interaction effect on growth parameters

Growth of plant was found to be influenced by the interaction of hormones and nutrients. Retardation in the plant height of gobhi sarson (*Brassica napus* L.), with the foliar application of ethrel at all the levels of

nitrogen was noted and the reduction was more pronounced in the absence of nitrogen (Grewal *et al.*, 1993). Flower number of different crops was found to be positively responsive towards exogenous application of growth substances (Morgan *et al.*, 1983; Friends, 1985). Grewal *et al.* (1993) noted that in a field grown *Brassica napus* L. foliar spray of 500 µL/L ethrel with basal 50 kg N/ha, resulted in more LAI, whereas at 100 kg N/ha, 1000 µL/L ethrel proved to be more beneficial. The findings are in close conformity with Bengal *et al.* (1982) and Singh *et al.* (1987). Ethrel spray (400 or 600 µL/L) along with basal (45 or 60 kg/ha) and foliar application of (0 or 10 kg/ha) of N, increased leaf area index and dry mass of mustard (Khan, 1996b). In a study on mustard, Khan *et al.* (2000) reported that at 0 or 40 kg N/ha, ethrel did not produce any significant effect, but at basal 80 kg N/ha, ethrel affected growth parameters like LAI and total dry matter.

2.8.2 Interaction effect on photosynthetic parameters

2.8.2.1 Chlorophyll content

Ethrel at 500 µL/L significantly improved the chlorophyll content in leaves of *Brassica napus* when 50 and 100 kg N/ha was applied. However, under no nitrogen application, higher dose of ethrel (1000 and 1500 µL/L) showed detrimental effects (Grewal *et al.*, 1993).

Grewal and Kolar (1990) reported that application of 500, 1000 and 1500 µL/L of ethrel reduced chlorophyll content when no N was applied but the reduction was only significant for 1500 µL/L ethrel at 0 and 50 kg N/ha. However, 500 and 1000 µL/L of ethrel at 100 kg N/ha significantly increased the chlorophyll content of leaves in *Brassica juncea* compared with water sprayed plants.

2.8.2.2 Photosynthesis

Grewal *et al.* (1993) observed indirect evidence of photosynthetic activities by enhancing chlorophyll content and retaining higher LAI with nitrogen (50 and 100 kg N/ha) and spray of ethrel (500 µL/L) in *Brassica*

napus. Khan *et al.* (2000) also reported that at basal 80 kg N/ha, ethrel spray improved LAI, thus resulting in more solar radiation being retained and enhanced net photosynthetic rate in Indian mustard (*Brassica juncea* L.)

2.8.2.3 Photosynthetic active radiation

Since the growth and crop productivity of crop species are governed to a great extent by its surrounding environment, hence any change in the quality of solar radiation would certainly influence the growth and productivity of several crop species in various agro-climatic zones (Parry, 1992; Sinha, 1992; Singh, 1997). The rate of photosynthesis and photosynthetically active radiation are highly influenced with leaf development and canopy structure (Ramanujan and Mohan Naidu, 1995).

In absence of N, ethrel at 1000 and 1500 µL/L significantly reduced the interception of PAR, while increase in nitrogen application (50 and 100 kg N/ha) resulted in improvement in interception of PAR (Grewal *et al.*, 1993). Similarly, in another study, Grewal and Kolar (1990) observed that increase in N (from 0 to 50 and 50 to 100 kg/ha) helped the crop canopy to trap more radiation. Ethrel at 500 µL/L concentration improved the radiation interception at 50 and 100 kg N/ha. At basal 60 kg N/ha and foliar 10 kg N/ha ethrel improved photosynthetic activities, improving crop canopy and retaining higher LAI during development phase of *Brassica juncea* (Khan, 1996b).

2.8.3 Interaction effect on nutrient uptake

Salama and Bazas (1987) reported the significant interaction effect between growth regulators and N, P and K fertilizers on the copper content of sunflower on calcarcious sandy loam soils. Erdei and Dhakal (1980) reported that ethrel stimulated K uptake in wheat. In *Brassica juncea* increase in N uptake with ethrel and N application has been reported by Khan *et al.* (2000).

2.8.4 Interaction effect on yield parameters

Enhanced seed yield in *Brassica napus* in response to N application was more pronounced with spray of ethrel. Application of 50 kg N/ha and spray of

ethrel (500 µL/L) significantly improved the grain yield and further improvement was observed with 100 kg N/ha and 1000 µL/L ethrel (Grewal and Kolar, 1993). Khan (1996b) reported that ethrel in association with nitrogen significantly increased pods per plant, seed per pod, 1000 seed weight, seed yield, oil content and oil yield in mustard. However, ethrel proved less effective at lower nitrogen dose because of insufficient availability of photosynthates. The number of pods per plant and number of seeds per pod increased sufficiently with 500 and 1000 µL/L ethrel only at 50 and 100 kg N/ha in *Brassica juncea*. At 50 kg N/ha, ethrel at 500 µL/L significantly improved seed yield and resulted in an increase in seed weight (Grewal and Kolar, 1990). Khan *et al.* (2000) reported that ethrel enhanced pods per plant, seed yield and seed yield merit of Indian mustard. However, the response of mustard was greater with the application of 80 kg N/ha than 0 and 40 kg N/ha.

2.9 Concluding Remarks

The foregoing review clearly established the fact that plant growth regulators are potent chemicals for enhancing performance of many crops. They exhibit pronounced interaction effect with nutrients. However, only few studies regarding the interaction effect of ethylene sources with nitrogen in mustard has been conducted. These studies do not provide in depth insight on the role of ethylene sources on nitrogen metabolism and involvement of ethylene sources on physiological aspects of plant growth and development. The work on the interaction effects of ethylene sources like, ethrel with nitrogen seems to have been neglected particularly in mustard. Therefore, an in depth study on the physiological response of mustard to ethrel and nitrogen is highly desirable. The research work reported in the subsequent chapter is related to this aspect in order to fill the existing lacuna in the studies on ethrel with nitrogen interaction for better understanding of role played by ethrel in determining growth and productivity of mustard grown with nitrogen doses.

CHAPTER–3
MATERIALS AND METHODS

CONTENTS

MATERIAL AND METHODS

MATERIALS AND METHODS

A comprehensive detail of material used and methodology adopted during the course of the present investigation are presented in this chapter.

3.1 Experimental Material

The term rapeseed is used to cover sarson, toria and taramira, whereas the term mustard refers only to 'rai'. Seeds of mustard (*Brassica juncea* L. Czern & Coss.) of two cultivars, namely Alankar and PBM16 were used as experimental material.

Seeds of the above cultivars were obtained from the Indian Agricultural Research Institute, New Delhi, India, and are recommended equally well for cultivation under drier and wet conditions.

3.1.1 Nomenclature

Indian *Oleiferous Brassicae* are divided into four groups.

1. Brown mustard, commonly called 'rai' (raya or laha) *Brassica juncea* (L.) Czern & Coss.

2. Sarson (i) Yellow Sarson – *Brassica campestris* L. var. Sarson Prain.

(ii) Brown Sarson – *Brassica campestris* L. var. Dichotoma Watt.

3. Toria (lahi or maghi lahi) *Brassica compestris* L. var. Toria Duth

4. Taramira or tara (*Eruca sativa* Mill.)

In addition, there are two other species, namely *Brassica nigra* Koch (Banarasi rai) and *Brassica juncea* var. Rugosa (pahadi rai) which do not fall under any of the four groups, and are grown to a limited extent.

3.1.2 Botanical description

Rape and mustard are annual herbs. Roots, in general, are long and tapering. Toria is more or less a surface feeder but brown mustard has long roots, with limited lateral spreads, enabling its successful cultivation under drier conditions. Yellow sarson has both extensive and lateral spreads. The

height of the stem varies from 0.45m (in some cultivars of toria) to 1.90m (in yellow sarson). In toria and brown sarson, the branches arise at an angle of 30° to 40°. In yellow sarson, the branches arise laterally at an angle of about 10° to 20° and give the plant a narrow and pyramidal shape. The inflorescence is a corymbose raceme. In the case of yellow sarson, the four petals are spread apart, whereas in brown sarson and toria, the petals overlap or may be placed apart, depending upon the cultivar. The flowers bear a hypogynous syncarpous ovary. In brown sarson and toria, the ovary is bicarpellary, whereas in case of yellow sarson, it may be tri or tetra-carpellary.

The fruit is a siliqua. The pods are two, three or four valved, depending on number of carpels in the ovary. The flowers begin to open from 8 a.m. and continue upto 12 noons.

3.2 Experimental Site

Five field experiments were conducted at the Experimental field of the Aligarh Muslim University, Aligarh, India.

3.3 Agro-Climatic Conditions

3.3.1 Topography

Aligarh has an area of 5,024 sq. km and is situated at 27°52'N latitude, 78°51'E longitude and 187.45m altitude above sea level.

3.3.2 Climate

It has a semi arid and subtropical weather with severest hot dry summers and intense cold winters.

3.3.3 Temperature

The winter stretches from middle of the October till the end of March. A gradual decrease in the temperature in December and January is observed, reaching as low as 15°C and 13°C, and lowest recorded for any single day is 2°C and 0.5°C respectively. The summer season extends from April to the end of June. In this season, a gradual increase in temperature is recorded, which attains its maximum, sometimes in the month of June upto 46°C (Fig. 1).

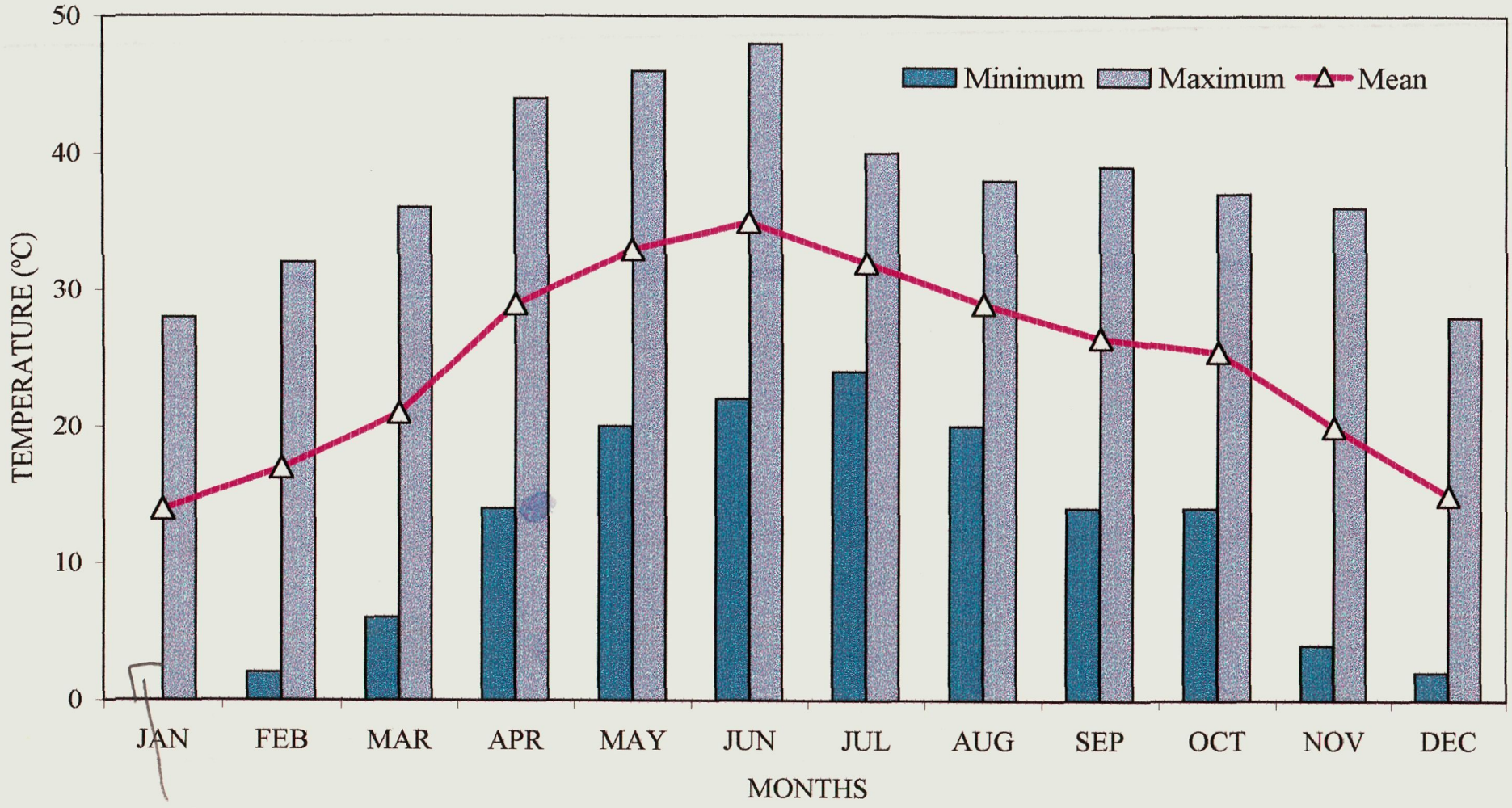


Fig. 1. Monthly temperature variation at Aligarh

3.3.4 Rainfall

The mean annual rainfall is about 847.3mm. More than 85% of the total downpour is derived during a short span of four months from June to September. The remaining rain drops are received during winter. These showers are very useful for winter crops. However, they are sometimes accompanied with high wind velocity and hailstorm (Figs. 2-3).

3.4 Meteorological Inputs

Meteorological data for the present study were documented at the Meteorological Observatory, Department of Physics, Aligarh Muslim University, Aligarh, India.

3.5 Soil Characteristics

Random soil samples were collected from various chosen spots, spread over the entire experimental crops upto depth of 15 cm, and analysed for physico-chemical characteristics of the soil. Data obtained on chemical characteristics and physical constant for soil are presented in Table 1. The soil was also analysed for moisture content at different growth stages of the crop (Table 1a).

3.6 Cultural Operations

The field experiments were laid out in randomized complete block design with three replicates for each treatment. The individual plot size was 10 sq m (2m X 5m).

3.6.1 Preparatory tillage

Before each trial, diligent ploughing of field was done to turn the soil for maximum aeration and weed eradication. The plots were made with proper boundaries along with necessary irrigation channels and were irrigated lightly before sowing to maintain proper moisture in the sub-surface of the soil.

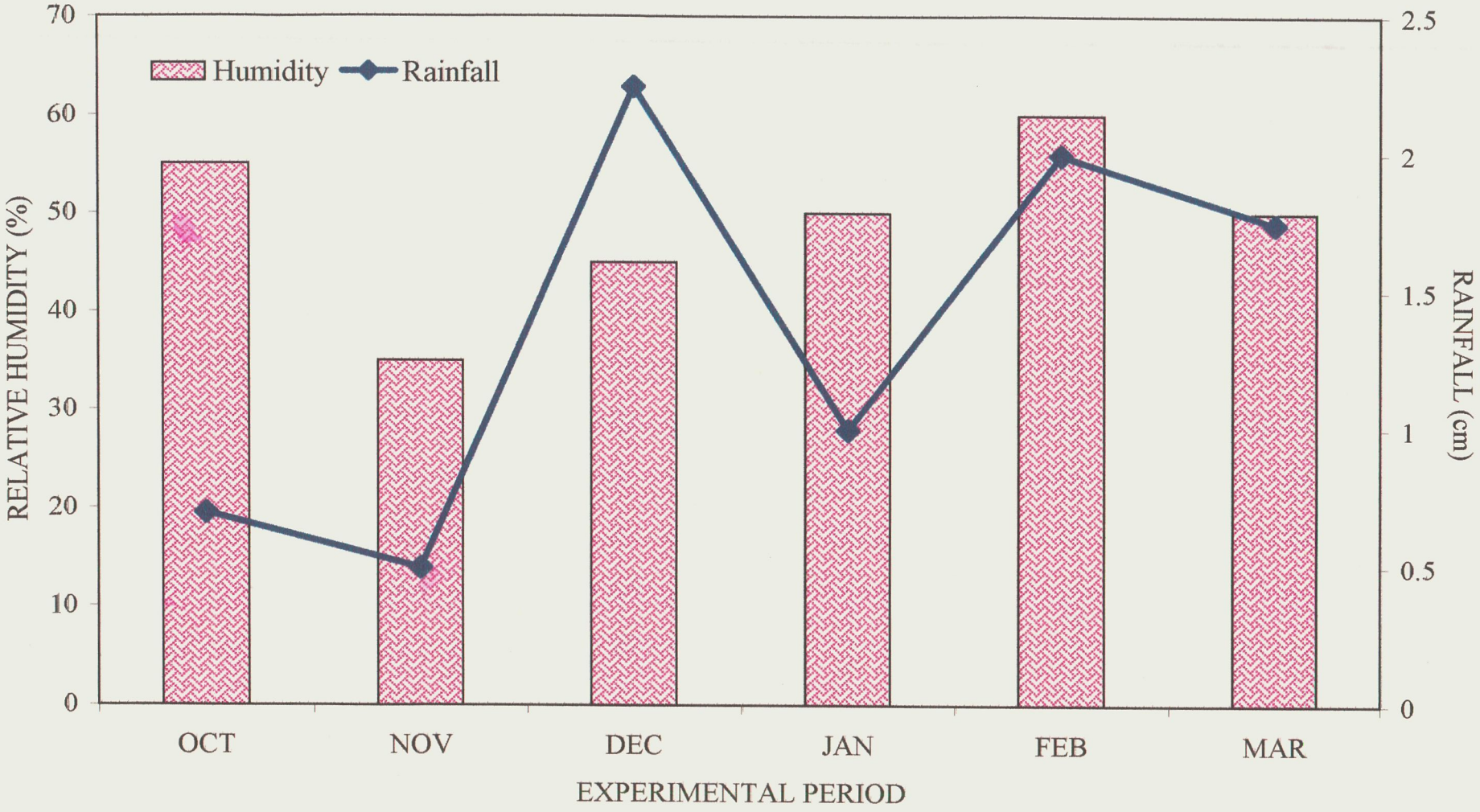


Fig. 2-3. Variation in relative humidity and rainfall during experimental period at Aligarh

Table 1 Physico-chemical characteristics of soil of the field used for experiments

	Experiment 1 (1998–1999)	Experiment 2 (1998–1999)	Experiment 3 (1999–2000)	Experiment 4 (1999–2000)	Experiment 5 (2000–2001)
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH (1 2)	8 0	8 4	7 8	7 9	7 6
EC (1 2) (m mhos/cm)	0 46	0 41	0 45	0 43	0 45
Available nitrogen (N) (kg/ha)	205	190	210	215	215

Table 1a Moisture content (%) of the soil sample during various growth stages of experimental period

Sampling stages	Experiment 1 (1998–1999)	Experiment 2 (1998–1999)	Experiment 3 (1999–2000)	Experiment 4 (1999–2000)	Experiment 5 (2000–2001)	
					Irrigated	Non-irrigated
Sowing (0d)	12 6	12 5	12 7	12 3	12 5	12 1
Flowering (60d)	11 5	8 6	11 4	8 2	11 6	8 3
Pod fill (80d)	9 6	6 6	9 4	6 4	9 6	6 3
Pod maturity (100d)	8 2	4 2	8 3	3 9	8 0	4 0
Harvest (120d)	6 0	3 1	6 2	2 9	6 3	2 9

3.6.2 Sowing

The seeds were sown by the usual behind the plough method at a rate of 10 kg/ha. A distance of 30 cm between rows and 15 cm between plants in each row was maintained.

3.6.3 Thinning

After establishment of the crop i.e. after 12 days of sowing, seedlings were thinned to maintain the uniformity (12 plants/m^2) of the plant population.

3.6.4 Crop protection

In order to check the aphid contagion, if any, insecticidal spray of Dimecron-100 was done. Hand weeding was done twice during the entire crop season to keep the experimental field free of weeds.

3.6.5 Irrigation

Before sowing 20 litre/m^2 irrigation was given to all plots maintained for irrigated and non-irrigated experiments. Thereafter this amount of irrigation was done only to the plots used for experiments done under irrigated conditions at 50d after sowing.

3.6.6 Plant sampling

Plants were sampled to record observations on various growth (Section 3.10), physiological (Section 3.11) and biochemical (Section 3.12) characteristics at different stages of plant growth. At maturity, plants were harvested to record yield characteristics (Section 3.13) by cutting at the ground level and were allowed for sun drying. After drying, threshing was done to clear the seeds for seed yield. Seeds were analysed for quality characteristics (Section 3.14).

3.7 Application of N Fertilizer

In Experiments 1 and 2, a recommended uniform soil application of 80 kg/ha was done to all plots, and in other experiments nitrogen (as urea) was applied according to the treatment and design of the experiments.

3.8 Application of Ethrel (2-Chloroethyl phosphonic acid)

Concentrations of ethrel used in experiments were sprayed as a.i.(µL/L) on leaves at 60d after sowing (flowering stage) at 600 litre /ha (600 mL/pot) using a hand sprayer (Hindustan Sprayers, New Delhi).

In mustard, flowering stage has been found as appropriate stage for spray (Khan, 1998; Khan *et al.* 2000). Early application of PGRs is not recommended because treatment effects are compensated for by prolonged duration of the crop photosynthesis and equal or increased assimilate partitioning to the seeds. This may result in non-significant difference in control and treated plants. The other reason for spray at flowering is that there exists internal hormonal imbalance during sink development and due to this, only 68 % flowers develop into pods. Therefore, spray at flowering stage brings hormonal status to suitable concentration and restricts flowers and pods abortion. Moreover, plants may be benefited additionally by spray at this stage by increasing the capacity of photoassimilate assimilation and sink strength since plants inherent capacity of these started declining.

3.9 Application of Silver Thiosulphate

Silver thiosulphate (STS) at 1mM concentration was sprayed at 60d after sowing (flowering stage) at 600 litre/ha (600 mL/plot). Application of ethrel was used to promote ethylene evolution, while the action of this gaseous plant growth regulator was blocked using silver ions applied as silver thiosulphate (STS). The objective was to test the hypothesis that ethylene has a central role in mediating plant responses. Silver thiosulphate solution was used to block the action of ethylene, as silver ions have been proposed to reduce the capacity of ethylene to interact with its receptors (Beyer, 1976). Silver thiosulphate is readily absorbed and transported by plants (Morgan *et al.*, 1993).

3.10 Experimentation

3.10.1 Experiment 1

This experiment was a factorial performed according to randomized complete block design during the winter season of 1998-99. The experiment was performed to assess the effect of leaf-applied 0, 100, 200, 400 and 600 µL/L of ethrel (2-chloroethyl phosphonic acid, 99.9 % a.i. CDH Bombay). The ethrel was applied on Alankar and PBM 16 cultivars of mustard (*Brassica juncea* L.) at 60 d after sowing (flowering stage). Alankar is a well adapted cultivar grown in the region, whereas PBM16 is a newly released cultivar. Ethrel was sprayed at a rate of 600 litre/ha (600 mL/plot) together with 0.5% teepol (a surfactant). In control group of plants, equal amount of de-ionized water with 0 5% teepol was sprayed.

The size of each plot was $10m^2$ (2m X 5m). The seeds were sown by the usual behind the plough method at a rate of 10 kg/ha. Each treatment was replicated thrice. Irrigation was done once during the entire season of the crop. Spray of an insecticide (Dimecron-100) was done to check aphid contagion, if any.

The scheme of the treatments is summarized in the Table 2 and ANOVA is given in the Table 2a.

At 20 days interval i.e. 80 (pod fill), 100 (pod maturity) and 120 d (harvest) after sowing, five plants from each plot were taken out with the help of hand hoe and various growth characteristics (Section 3.10) and biochemical characteristics (Section 3.12) were determined.

Physiological characteristics (Section 3.11) were studied at 80 and 100 d after sowing. At harvest (120 d after sowing), yield characteristics (Section 3.13) and quality characteristics (Section 3.14) were recorded.

3.10.2 Experiment 2

This experiment was also a factorial conducted simultaneously with Experiment 1 according to randomized complete block design, but the

Table 2. Scheme of treatments for Experiment 1 (1998–99)

	Ethrel (µL/L)				
Cultivars	0	100	200	400	600
Alankar	+	+	+	+	+
PBM16	+	+	+	+	+

Crop : Mustard (*Brassica juncea* L. Czern & Coss.) grown under irrigated conditions

Treatment : Spray at 60d after sowing (flowering stage) and 20 days interval thereafter.

Design : Randomized complete block design

Table 2a. Model of analysis of variance (ANOVA) of data from a 5x2 factorial experiment in randomized complete block design (Experiment 1)

Source of variation	d.f.	S.S.	M.S.S.	F. value
Replication	2			
Treatment	9			
Spray (S)	4			
Cultivar (C)	1			
Interaction (S x C)	4			
Error	18			
Total	29			

experiment was carried out under non-irrigated conditions. The scheme of the treatments and other details of observations are same as in Experiment 1.The scheme of treatments is given in Table 3 and ANOVA in Table 3a.

3.10.3 Experiment 3

A factorial experiment conducted according to randomized complete block design during winter season of 1999-2000 under irrigated conditions. The aim of the experiment was to investigate the effect of leaf-applied 0, 100 or 200 µL/L ethrel (selected on the basis of Experiment 1) at 60d after sowing (flowering stage) on growth, physiological, biochemical, yield and quality characteristics of mustard (*Brassica juncea* L.) cultivar Alankar. The cultivar Alankar was selected based on its better performance than PBM 16 in Experiment 1. The plants were grown with 0, 40, 60 and 80 kg N/ha. The N doses were selected on the basis of recommendation for cultivation of mustard. Basal 80 kg N/ha is recommended dose and the other doses 60 and 40 kg N/ha are two sub-optimal doses.

The scheme of the treatments is summarized in the Table 4 and ANOVA is given in Table 4a. All other plant growing cultivation practices, including size of plots, sowing method, seed rate, number of irrigation, weeding and pest control operations were kept same as in Experiment 1.

Sampling was done at 80, 100 and 120 d after sowing to record growth, physiological, biochemical, yield and quality characteristics as described for Experiment 1. Among biochemical characteristics, nitrate reductase activity in leaves was also determined in this experiment.

3.10.4 Experiment 4

This experiment was carried out simultaneously with Experiment 3, but under non-irrigated conditions in the winter season of 1999-2000. The aim of this factorial randomized complete block design experiment was to study the effect of leaf-applied 0, 100 or 200 µL/L ethrel at 60 d after sowing (flowering stage) on mustard (*Brassica juncea* L.) cultivar Alankar grown with basal 0,

Table 3. Scheme of treatments for Experiment 2 (1998–99)

	Ethrel (µL/L)				
Cultivars	0	100	200	400	600
Alankar	+	+	+	+	+
PBM16	+	+	+	+	+

Crop : Mustard (*Brassica juncea* L. Czern & Coss.) grown under non-irrigated conditions

Treatment : Spray at 60d after sowing (flowering stage)

Design : Randomized complete block design

Table 3a. Model of analysis of variance (ANOVA) of data from a 5x2 factorial experiment in randomized complete block design (Experiment 2)

Source of variation	d.f.	S.S.	M.S.S.	F. value
Replication	2			
Treatment	9			
Spray (S)	4			
Cultivar (C)	1			
Interaction (S x C)	4			
Error	18			
Total	29			

Table 4 Scheme of treatments for Experiment 3 (1999–2000)

Basal nitrogen levels (kg N/ha)	Ethrel (µL/L)		
	0	100	200
N_0	+	+	+
N_{40}	+	+	+
N_{60}	+	+	+
N_{80}	+	+	+
Crop	Mustard (*Brassica juncea* L Czern & Coss) grown under irrigated conditions		
Treatment	Spray at 60d after sowing (flowering stage)		
Design	Randomized complete block design		

Table 4a Model of analysis of variance (ANOVA) of data from a 3x4 factorial experiment in randomized complete block design (Experiment 3)

Source of variation	d f	S S	M S S	F value
Replication	2			
Treatment	11			
Spray (S)	2			
Nitrogen (N)	3			
Interaction (S x N)	6			
Error	11			
Total	35			

40, 60 and 80 kg N/ha on the plant characteristics described for Experiment 3. All practices of cultivation and observation details recorded at various growth stages are similar to Experiment 3. The scheme of treatments is summarized in the Table 5 and ANOVA is given in Table 5a.

Experiment 1 and 2 were conducted separately in one season in view of easy handling of the experiments, but for comparison of effect of ethrel spray treatments under irrigated and non-irrigated conditions analysis of some important data as group comparison was done. Similar analysis was carried out for Experiment 3 and 4.

3.10.5 Experiment 5

This factorial experiment was performed according to randomized complete block design during winter season of 2000-2001. Based on the findings of Experiment 3 and 4, application of 0 and 200 µL/L ethrel or 1mM silver thiosulphate (STS) on mustard (*Brassica juncea* L.) cultivar Alankar grown under irrigated and non-irrigated conditions was done at 60 d after sowing (flowering stage). A uniform basal application of 80 kg N/ha was given. The aim of this experiment was to confirm the findings on effects of ethrel on plant characteristics as found in Experiment 3 and 4. Because of this reason silver thiosulphate, which inhibits physiological action of ethylene was used in the experiment along with ethrel. Ethrel is a source of ethylene and its effects are manifested through physiological action of ethylene. The scheme of the treatment is summarized in the Table 6 and ANOVA is given in Table 6a.

All other plant growing cultivation practices, including size of plots, sowing methods, seed rate, number of irrigation, weeding and pest control operations were kept same as in Experiment 3 and 4.

Sampling was done at 80, 100, 120 d after sowing to assess the growth performance in terms of leaf area and dry weight per plant, physiological, yield and quality characteristics were studied. The details of the characteristics studied are given in the following pages.

Table 5 Scheme of treatments for Experiment 4 (1999–2000)

Basal nitrogen levels (kg N/ha)	Ethrel (μL/L)		
	0	100	200
N_0	+	+	+
N_{40}	+	+	+
N_{60}	+	+	+
N_{80}	+	+	+
Crop	Mustard (*Brassica juncea* L. Czern & Coss.) grown under non-irrigated conditions		
Treatment	Spray at 60d after sowing (flowering stage)		
Design	Randomized complete block design		

Table 5a Model of analysis of variance (ANOVA) of data from a 3x4 factorial experiment in randomized block design (Experiment 4)

Source of variation	d f	S.S	M S S	F. value
Replication	2			
Treatment	11			
Spray (S)	2			
Nitrogen (N)	3			
Interaction (S x N)	6			
Error	11			
Total	35			

Table 6. Scheme of treatments for Experiment 5 (2000–2001)

Irrigation	Spray treatment		
	0 Water	200 µL/L Ethrel	1mM Silverthiosulphate
Irrigated	+	+	+
Non-irrigated	+	+	+

Crop : Mustard (*Brassica juncea* L. Czern & Coss.) cv. Alankar grown under irrigated and non-irrigated conditions

Treatment : Spray at 60d after sowing (flowering stage)

Design : Randomized complete block design

Table 6a. Model of analysis of variance (ANOVA) of data from a 3x2 factorial experiment in randomized complete block design Experiment 5

Source of variation	d.f.	S.S.	M.S.S.	F. value
Replication	2			
Treatment	5			
Spray (S)	2			
Irrigation (I)	1			
Interaction (S x I)	2			
Error	10			
Total	17			

3.11 Biometric Observation

The observations were made at 20 days interval after spray treatment i.e., at 80 (pod fill), 100 (pod maturity) and 120 (harvest) d after sowing. At each sampling five plants from each plot were cut at the soil level, washed with water and dried with blotting paper to record growth, physiological and biochemical characteristics. At harvest, 12 plants, equipment to $1m^2$ land area were removed to record the yield characteristics.

3.12 Growth Characteristics

The following growth characteristics were studied at 80, 100 and 120 d after sowing in Experiments 1-4.

1. Plant height
2. Plant leaf area
3. Leaf area index
4. Specific leaf area
5. Specific leaf weight
6. Plant dry weight
7. Dry weight of different plant parts
   - (i) Leaf dry weight
   - (ii) Stem dry weight
   - (iii) Pod dry weight
8. Per cent distribution of dry weight
   - (i) Leaf
   - (ii) Stem
   - (iii) Pod
9. Leaf fresh weight
10. Leaf turgid weight
11. Relative water content in leaf

In Experiment 5, the following growth characteristics were studied.

1. Plant leaf area

2 Plant dry weight

3.12.1 Plant leaf area

Leaf area was determined by gravimetric method Leaf area of about 10 % of total leaves from each treatment was determined by tracing on a graph sheet and dry weight for these leaves was recorded Leaf area/plant was computed by using leaf dry weight/plant and dry weight of those leaves for which the area was estimated (Watson, 1958) using the following formula

$$LA = \frac{LA_1 \times W_2}{W_1}$$

LA_1 = Leaf area of the leaves traced on graph paper

W_1 = Dry weight of the leaves for which area was traced on graph paper

W_2 = Total leaf dry weight/plant

3.12.2 Leaf area index

Leaf area index (LAI) was calculated on the formula suggested by Watson (1958)

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.12.3 Specific leaf area

Specific leaf area (SLA) represents the leaf area of unit amount of leaf biomass This was calculated as leaf area divided by leaf dry weight

$$SLA = \frac{\text{Leaf area}}{\text{Leaf weight}}$$

3.12.4 Specific leaf weight

Specific leaf weight (SLW) is the measurement of allocation of leaf dry weight per unit of leaf area It was calculated as leaf dry weight divided by leaf area

$$SLW = \frac{\text{Leaf weight}}{\text{Leaf area}}$$

3.12.5 Dry weight

Dry weight of different plant parts was recorded after drying them in an oven for 48 h at 80 °C.

3.12.6 Leaf fresh weight and turgid weight

The sampled plants were divided into different parts like leaf, stem and pod corresponding to different sampling stages. Leaf fresh weight was recorded and samples were placed in water and their turgid weight was recorded accordingly.

3.12.7 Leaf relative water content

Relative water content (RWC) of leaves was expressed as percentage of the water content of the fully turgid leaves and calculated as follows.

$$\text{Relative water content (\%)} = \frac{W_F - W_d}{W_t - W_d} \times 100$$

Here, W_t = Weight of the fully turgid leaves

W_F = Fresh weight of the leaves

W_d = Dry weight of the leaves

3.13 Physiological Characteristics

Following physiological parameters were studied at 80 and 100 d after sowing in all experiments.

1. Rate of photosynthesis
2. Stomatal conductance
3. Internal CO_2 concentration
4. Transpiration rate
5. Carboxylation efficiency
6. Photosynthetic water use efficiency
7. Plant water use efficiency

In Experiments 3-5, in addition to the above mentioned parameters following characteristics were also studied.

1. 1-Aminocyclopropane carboxylic acid (ACC) content
2. ACC oxidase
3. Ethylene evolution

3.13.1 Rate of photosynthesis

The data on rate of photosynthesis, stomatal conductance, internal CO_2 concentration and transpiration rate were measured in fully expanded top leaf of each main axis of plant using the Li COR–6200 Portable photosynthesis system (Nebraska, USA) at 1250 μ mol m^{-2} s^{-1} photosynthetically active radiation at 1100-1200 hours (temperature 23° C, relative humidity 72 %). The care was taken to use leaves of the same age for measurement of photosynthesis in control and treated plants. Each observation was replicated twice for control and treated plants and average of these was taken as a replicate.

3.13.2 Carboxylation efficiency

Carboxylation efficiency was computed by dividing the photosynthesis by internal CO_2 concentration and expressed in percentage.

$$\text{Carboxylation efficiency (\%)} = \frac{\text{Photo}}{C_i} \times 100$$

3.13.3 Photosynthetic water use efficiency

Photosynthetic water use efficiency is a measure of CO_2 assimilation and has direct relation with rubisco activity (Vanden Boogard *et al.*, 1996). It was expressed as the ratio of photosynthesis rate to stomatal conductance (A/g_s) to avoid effects of small differences in vapour pressure between measurements (Von Cammerer and Farquhar, 1981).

3.13.4 Plant water use efficiency

Water use efficiency was calculated as the ratio of biomass to cumulative transpiration (Vanden Boogard *et al.*, 1996).

$$\text{Plant water use efficiency} = \frac{\text{Biomass}}{\text{Transpiration}}$$

3.13.5 Estimation of 1-aminocyclopropane-1-carboxylic acid (ACC)

At sampling times, 1 g of leaf sample was homogenized in 10 ml of 80 % ethanol and then extracted under reflux with boiling ethanol for 30 min. It was then filtered through four layers of fine gauze and evaporated to dryness. The process was repeated with the addition of 0.5 ml chloroform. The residue was suspended in 2 ml double-distilled water, and then centrifuged for 20 min at 27000 g (Mc Keon *et al.* 1982). The ACC content in the aqueous extract was determined by its chemical conversion to ethylene after the addition of NaOCl (Lizada and Yang 1979). ACC content in the extract was estimated assuming that the percentage conversion of ACC to ethylene in the extract was identical to that of ACC added as an internal standard.

3.13.6 Assay of ACC oxidase activity

ACC oxidase activity was measured as ability of leaves to convert exogenous ACC to ethylene. Leaf sample (0.5 g) was cut into small pieces and incubated with 0.5 mL of 5 mM ACC. After flushing with air, the tubes were capped and incubated in light for 1 h under the same conditions used for plant growth (Vioque and Castellano, 1994). The ethylene evolved during incubation was determined on gas chromatograph (Nucon GLC 5700, India), as described in Section 3.11.3

3.13.7 Ethylene evolution

For ethylene measurement leaf material was trimmed to small pieces, weighed and placed in 30 ml tubes, which were stoppered with rubber secure cap and placed in light for 2 h under the same conditions as used for plant

growth. Ethylene content in the gas phase of tubes was determined from 1 ml samples were removed from the tubes and injected into a Nucon GLC 5700 gas chromatograph fitted with a flame ionisation detector and 1.8 m x 4 mm glass column packed with 80-100 mesh porapack-N. The oven temperature was 100°C. The flow rates of nitrogen and hydrogen were 30 ml min^{-1}, and of oxygen was 300 ml min^{-1}. Ethylene identification was based on the retention time compared with a pure ethylene standard

3.14 Biochemical Characteristics

Following parameters were studied:

1. Nitrate reductase activity
2. N content
3. N accumulation

Nitrate reductase activity in fresh leaves was estimated and dried plant material, collected at different sampling stages was used for the estimation of N content and its accumulation. The details of the estimation procedure are given in the following pages.

3.14.1 Assay of nitrate reductase activity

Enzyme nitrate reductase catalyses the reduction of nitrate to nitrite.

$$NO_3^- + NADH + H^+ \xrightarrow{\text{Nitrate reductase}} NO_2^- + NAD + H_2O$$

Leaf nitrate reductase activity (NRA) was estimated *in vivo* by the method of Jaworski (1971), which is based on the reduction of nitrate to nitrite. The nitrite formed was then determined spectrophotometrically.

Fresh leaf sample (200 mg) was transferred to polythene vials, containing 2.5 mL of phosphate buffer (pH 7.0) and 0.5 mL of 0.2 M potassium nitrate solution (Appendix) was added followed by addition of 2.5 mL of 5 % isopropanol (Appendix). Finally, 2 drops of 0.5 % chloramphenicol solution (Appendix) was added to avoid bacterial growth in the medium. These vials were incubated for 2 hours in dark at 30°C.

3.14.1.1 Colour development

Incubated mixture (0.4 mL) was taken in a test tube to which 0.3 mL of 1 % sulphanilamide (Appendix) and 0.02 % naphthylethylenediamine hydrochloride (NED–HCl) were added. The test tube was left for 20 minutes for maximum colour development. The mixture was diluted again to 5 mL with sufficient amount of double distilled water. Then absorbance was read at 540 nm using a blank on spectrophotometer (SL171 Elico, Hyderabad, India).

3.14.1.2 Standard curve for NRA

30 mg of sodium nitrite ($NaNO_2$) was dissolved in 100 mL double distilled water. From this solution, various amounts was taken in ten different test tubes, viz., 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2 0 mL. To these 0.3 mL of 1 % sulphanilamide and 0.02 % NED–HCl were added. The solutions were diluted to 5 mL with double distilled water and the absorbance was read at 540 nm, using a blank on spectrophotometer (SL171 Elico, Hyderabad, India).

3.14.2 Nitrogen content

3.14.2.1 Digestion of plant samples for N content

Dried plant material was powdered and passed through 70- mesh screen and stored in polythene vials. This plant material was used for the estimation of N content.

100 mg of the oven dried powder from each replicate was transferred to a 50 mL Kjeldahl flask to which 2 mL of sulphuric acid was added. The content of the flask was heated on temperature-controlled assembly for about 2 hours to allow complete reduction of nitrates present in the plant material by organic matter itself. As a result, the contents of the flask were turned black. After cooling the flask for about 15 minutes, 0.5 mL of 30 % H_2O_2 was added drop by drop and the solution was heated again until the colour turns from black to light yellow. Again after cooling for 30 minutes an additional 3-4 drops of 30 % H_2O_2 were added, followed by heating for another 15 minutes.

The process was repeated until the contents of the flask turned colourless. The peroxide digested material was transferred from Kjeldahl flask to 100 mL volumetric flask with three washings of double distilled water. The volume of the flask was made up of to the mark with double distilled water. This peroxide digested material was used for the estimation of N content.

3.14.2.2 Estimation of nitrogen

Nitrogen was estimated according to Lindner (1944). A 10 mL aliquot of the digested material was taken in 50 mL volumetric flask. To this, 2 mL of 2.5 N NaOH and 1 mL of 10 % sodium silicate solution were added which neutralizes excess of acid and prevents turbidity. The volume of the solution was made upto the mark with double distilled water. In a 10 mL graduated test tube, 5 mL of this solution was taken and 0.5 mL of Nessler's reagent was added. The final volume was made up with double distilled water. The contents of the tube were allowed to stand for 5 minutes for maximum colour development and absorbance was read at 525 nm on spectrophotometer (SL171 Elico, Hyderabad, India).

3.14.2.2.1 Standard curve for nitrogen

50 mg ammonium sulphate was dissolved in 1 litre double distilled water. From this solution, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 ml were pipetted to ten different test tubes. The solution in each test tube was diluted to 5 mL with double distilled water. In each test tube, 0.5 mL Nessler's reagent was added and after 5 minutes, the absorbance was read at 525 nm on spectrophotometer (SL171 Elico, Hyderabad, India). A blank was run with each set of determination. Standard curve was plotted using different concentrations of ammonium sulphate solution versus absorbance and with the help of this standard curve the amount of nitrogen present in the sample was determined.

3.14.3 N accumulation

Nitrogen content of the plant at different sampling stages and their respective dry matter at these stages were used (as a product) to calculate the N accumulation

3.15 Yield Characteristics

Following parameters were recorded at harvest.

1. Number of pods per plant
2. Number of seeds per pod
3. 1000 seed weight
4. Seed yield
5. Biological yield
6. Harvest index
7. Oil yield

In addition to the above parameters, following parameters were also included in the study in Experiments 3-5 because these experiments included nitrogen as a treatment.

1. Seed N
2. Nitrogen harvest index
3. Nitrogen yield potential

3.15.1 Number of pods per plant

At harvest, 12 plants from each treatment equivalent to 1 m^2 land were removed. The pods were collected and counted.

3.15.2 Number of seeds per pod

Seeds of 12 pods from each plant in a treatment were collected and counted.

3.15.3 1000 seed weight

From the produce of the plot, 1000 seeds were randomly drawn and the weight was recorded.

3.15.4 Seed yield

Total seeds from one-meter square area of the plot were cleaned and weighed to compute the seed yield.

3.15.5 Biological yield

Total biological yield from one-meter square area was recorded from sun-dried samples before threshing.

3.15.6 Harvest index

Harvest index was computed by dividing the seed yield with biological yield and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.15.7 Seed N content per plant

Seed N content was determined as a product of N concentration and the dry weight of the seed.

3.15.8 Nitrogen harvest index

Nitrogen harvest index is a measure of distribution of nitrogen from vegetative part to seed. This was calculated by dividing the seed N with plant N.

$$\text{Nitrogen harvest index} = \frac{\text{Seed N}}{\text{Plant N}}$$

3.15.9 Nitrogen yield potential

Nitrogen yield potential denotes the efficiency of plants to mobilize total N contained in plants to seed during pod fill. This was calculated as a product of nitrogen harvest index and seed N i.e.

Nitrogen yield merit = Nitrogen harvest index x Seed N

3.15.10 Oil yield

The per cent oil content in seeds when multiplied with seed yield gave the oil yield.

3.16 Quality Characteristics

The seed samples were crushed to get a fine meal for extracting the oil after separating them from extraneous material. The oil was analysed for following quality parameters.

1. Oil content
2. Acid value
3. Iodine value
4. Saponification value

3.16.1 Determination of oil content

25 g of ground seeds meal was transferred to a Soxhlet apparatus and sufficient quantity of petroleum ether was added. The apparatus was kept on a hot water bath running at 60 °C for about 6 h, for extraction of oil. Petroleum ether from the extracted oil was evaporated after some time. The extracted oil was expressed as a percentage by mass of the seeds and was calculated by the following formula:

$$\text{Oil content (\%)} = \frac{m_0}{m_S} \times 100$$

Here, m_0 = Sum of the mass of oil

m_S = Seed sample mass

3.16.2 Determination of acid value

Acid value of oil is the amounts of potassium hydroxide spend to neutralize free acid in one gram of oil. It was determined by the following method (Anonymous, 1970).

2 g of oil was dissolved in 50 mL solvent mixture of 95 % alcohol and diethyl ether (1:1) in a 250 mL conical flask. Titration was carried out with 0.1

N potassium hydroxide. Phenolapthalien was used as an indicator and the amount of mL 'a' of 0.1 N NaOH required was noted. The acid value was calculated by the following formula.

$$\text{Acid value} = \frac{\text{'a'} \times 0.05661 \times 1000}{W}$$

Here, 'a' = ml of 0.1N KOH used in titration

W = weight of oil

3.16.3 Determination of iodine value

Iodine value of oil is the number of gm of iodine absorbed by 100 gm of oil and expressed as the weight of iodine. It was determined by using iodine monochloride method described below (Anonymous, 1970).

Oil (2 gram) was taken in a dry ground neck flask to which 10 mL carbon tetrachloride and 20 mL iodine monochloride solution were added. The flask was stopper and allowed to stand in a dark place for about 30 minutes. After 30 minutes, 15 mL potassium iodide and 100 mL double distilled water was poured into it with proper shaking. Titration was carried out with 0.1 N sodium thiosulphate ($Na_2S_2O_3$) solution using starch solution as an indicator. Number of mL 'a' of sodium thiosulphate used was noted. For blank, similar operation was put in practice without the oil and the number of ml 'b' of 0.1 N sodium thiosulphate solution used was noted. Iodine value was calculated by the following formula (Anonymous, 1970).

$$\text{Iodine value} = \frac{(b - a) \times 0.01269 \times 100}{W}$$

Here, a = number of mL of 0.1 N $Na_2S_2O_3$ solution used in the sample

b = number of mL of 0.1 N $Na_2S_2O_3$ solution used in blank

W = weight of oil

3.16.4 Determination of saponification value

Saponification value of oil is the amount of mg of KOH consumed by 1gm of the oil to neutralize the fatty acid resulting from complete hydrolysis.

2 gm oil was taken in a 250 mL conical flask to which 25 mL of 0.5 N KOH was added. The flask was attached with reflux condenser and heated on water bath for about 1h with frequent rotation of the contents of the flask. The excess of alkali was titrated with 0.5 N HCl. The number of mL (a) of 0.5 N HCl was noted. A similar practice was repeated without oil and the number of mL (b) of 0.5 N HCl required was noted (Anonymous, 1970). Saponification value was calculated by the following formula:

$$\text{Saponification value} = \frac{(b - a) \times 0.02805 \times 1000}{W}$$

Where a and b are number of mL of 0.05 N HCl used in the sample and blank titration respectively, and W is weight of oil

3.17 Statistical Analysis

All the experimental data were subjected to statistical analysis by adopting analysis of variance techniques according to the design of the experiments (Gomez and Gomez, 1984) and the significance of the results were determined at 5% levels of probability. Pooled analysis of Experiments 1 and 2 and Experiments 3 and 4 was performed from a split plot design to evaluate the effect of combinations of factors. If the data were found significant, Least Significant Difference (LSD) was calculated. Correlation values between various traits were also worked out.

CHAPTER–4
EXPERIMENTAL RESULTS

CONTENTS

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

It has been mentioned in Materials and Methods section that the two experiments (1 and 2) and (3 and 4) were conducted on the same lines with difference of irrigated and non-irrigated conditions. The results of Experiment 1 and 2, and Experiment 3 and 4 are described together in the following pages. The data of Experiment 1 (Tables 7–34), Experiment 2 (Tables 35–62), pooled analysis of Experiment 1 and 2 (Tables 63–71), Experiment 3 (Tables 72–104), Experiment 4 (105–137), pooled analysis of Experiment 3 and 4 (Tables 138–146) and Experiment 5 (Tables 147–180) are given at the end of the thesis.

4.1 Experiment 1 and 2

In these experiments concentrations of ethrel applied at 60d after sowing were 0, 100, 200, 400 and 600μL/L on Alankar and PBM16 cultivars of mustard. Growth characteristics, plant height, plant leaf area, leaf area index, specific leaf area, specific leaf weight, plant dry weight, dry weight and its per cent distribution in leaf, stem and pod, leaf fresh weight, leaf turgid weight and leaf relative water content; biochemical characteristics, N concentrations and its accumulation were recorded at 80, 100 and 120 DAS. Physiological characteristics, net photosynthetic rate, stomatal conductance, internal CO_2 concentration, transpiration rate, carboxylation efficiency, photosynthetic water use efficiency and plant water use efficiency were recorded at 80 and 100 DAS. At harvest pod number, seed number, 1000 seed weight, seed yield, biological yield, harvest index, oil yield, oil content, acid value, iodine value and saponification value of oil were determined.

4.1.1 Growth characteristics

4.1.1.1 Plant height

Plant height was significantly affected by ethrel spray and both cultivars differed each other at all growth stages. The interaction effect between ethrel

spray and cultivar was non-significant (Tables 7, 35). Similar response was noted in both the experiments.

Spraying of 200µL/L ethrel registered maximum effect on plant height and water spray recorded minimum value for plant height at all growth stages. Among the cultivars, Alankar was taller than PBM16 at all sampling times (Tables 7, 35) in Experiment 1 as well as in Experiment 2.

4.1.1.2 Plant leaf area

Crop canopy, which is represented by leaf area, was significantly affected by ethrel spray and cultivars also differed significantly at all sampling times in the two experiments. The interaction effect between these two was found significant at 80 DAS in Experiment 1 and 80 and 100 DAS in Experiment 2 (Tables 8, 36).

A concentration of 200µL/L ethrel showed maximum value at all three growth stages and significantly minimum value was recorded for water sprayed under irrigated and non-irrigated conditions.

Alankar showed maximum leaf area as compared to PBM16 at all sampling stages in the two experiments. It was observed that 200µL/L ethrel spray on Alankar gave maximum value and water spray on PBM16 gave minimum value at 80 DAS in Experiment 1. Similar effect was noted at 80 and 100 DAS in Experiment 2 (Tables 8, 36).

4.1.1.3 Leaf area index

Leaf area index was significantly affected by ethrel spray and cultivars differed significantly at all sampling times. Interaction effect between ethrel spray and cultivar was significant only for 80 DAS. A similar response was noted in both the experiments (Tables 9, 37).

Significantly maximum value was recorded with 200µL/L ethrel spray at every growth stage and minimum value was found in water spray. Alankar showed higher leaf area index than PBM16.

Among different interactions, 200µL/L ethrel spray on Alankar registered maximum value and minimum value was recorded in water spray on PBM16 (Tables 9, 37).

4.1.1.4 Specific leaf area

Ethrel spray significantly affected specific leaf area and cultivars differed significantly for this characteristic at all sampling times in both the experiments. The interaction effect of these two remained non-significant in both the experiments (Tables 10, 38).

Spray of 200µL/L ethrel and water gave maximum and minimum values respectively in both the experiments. Alankar showed maximum and PBM16 the minimum values.

4.1.1.5 Specific leaf weight

Values recorded in ethrel spray and cultivar differed significantly at all the sampling times in both the experiments. Interaction effect was noted to be non-significant in both the experiments (Tables 11, 39).

Significantly maximum and minimum values were recorded with water spray and 200µL/L ethrel spray respectively. The trend was similar in the two experiments, and Alankar registered higher value than PBM16.

4.1.1.6 Plant dry weight

Plant dry weight was affected by ethrel spray at every growth stage. The effect of ethrel spray on cultivars differed significantly at 80 DAS only, however, at other sampling times, the two cultivars responded equally to every spray treatment (Tables 12, 40) in Experiment 1. Highest plant dry weight was recorded with 200µL/L ethrel spray at all sampling times, while the lowest value was found in water sprayed control.

Alankar showed maximum plant dry weight as compared to PBM16. Among interactions, 200µL/L ethrel spray on Alankar proved best and gave significantly maximum value as compared to other interactions. Minimum value was noted in water sprayed on PBM16.

4.1.1.7 Dry weight of different plant parts

4.1.1.7.1 Leaf dry weight

Ethrel spray significantly affected leaf dry weight at all sampling times. Ethrel spray on the two cultivars significantly differed at 80DAS in Experiment 1 and at 100 DAS in Experiment 2 (Tables 13, 41).

Maximum leaf dry weight was recorded with 200µL/L ethrel spray at all sampling times in both the experiments. Significantly minimum value was found in water sprayed control treatments.

Among the cultivars, Alankar showed maximum value as compared to PBM16 in the two experiments. Among interactions, 200µL/L ethrel spray on Alankar proved best and gave significantly higher value while the lowest value was recorded in water sprayed on PBM16.

4.1.1.7.2 Stem dry weight

Stem dry weight was significantly affected by ethrel spray at all sampling times in both the experiments. Effect of ethrel spray on the two cultivars significantly differed at 80 and 100 DAS in Experiment 1, whereas the cultivars responded similarly to the concentrations of ethrel in Experiment 2 at all sampling times (Tables 14, 42).

In both the experiments, 200µL/L ethrel spray resulted in maximum value for stem dry weight, while minimum value was found in water sprayed control.

Alankar registered higher dry weight than PBM16 at all sampling times under irrigated and non-irrigated conditions. Regarding the interaction between ethrel spray and cultivar, it was observed that 200µL/L ethrel spray on Alankar gave maximum value at 80 and 100 DAS.

4.1.1.7.3 Pod dry weight

Effect of ethrel spray was significant at all sampling times and the interaction effect between spray and cultivar was found significant at 100 DAS in Experiment 1 and 2 (Tables 15, 43).

A 200µL/L ethrel spray gave highest value at all sampling times. Significantly lowest value was recorded for water spray control. At all growth stages, Alankar showed higher value than PBM16.

Among the interactions, 200µL/L ethrel spray on Alankar gave maximum value. However, minimum value was registered with water spray on PBM16 (Tables 15, 43).

4.1.1.8 Per cent distribution of dry weight in plant parts

4.1.1.8.1 Leaf

Effect of ethrel spray was found significant at all sampling times in both the experiments. The two cultivars differed significantly at 100 and 120 DAS in Experiment 2. The interaction effect between ethrel spray and cultivar was non-significant in both the experiments (Tables 16, 44).

Significantly maximum value was recorded with 200µL/L ethrel spray at every growth stages, while minimum value was found with water spray.

Value recorded for Alankar was higher than PBM16, when they differed significantly (Tables 16, 44).

4.1.1.8.2 Stem

Effect of ethrel spray was significant at all the three growth stages in both the experiments. Similarly, cultivars differed each other significantly. The interaction effect was significant at 100 DAS in Experiment 1, but it was non-significant at all sampling times in Experiment 2.

Per cent stem dry weight decreased with the increase in ethrel concentration at all growth stages and water-sprayed control registered maximum value. Significantly minimum value was recorded with 200µL/L ethrel spray. The trend was similar in both the experiments.

At all growth stages, PBM16 gave more value than Alankar. The interaction effect of water spray and PBM16 gave maximum value. Minimum value was given by 200µL/L ethrel sprayed on Alankar (Tables 17, 45).

4.1.1.8.3 Pod

Distribution of dry weight towards pods was significantly influenced by ethrel spray and cultivar also differed significantly. Similar response was noted in the Experiment 1 and 2. However, interaction effect of ethrel spray and cultivar was significant at 100 DAS in Experiment 1 and non-significant at all sampling times in Experiment 2 (Tables 18, 46).

A 200µL/L ethrel spray showed maximum value and significantly minimum value was registered for water sprayed control in both the experiments.

Alankar showed higher value than PBM16 at all sampling times in both the experiments. Spray of 200µL/L ethrel on Alankar proved best and gave maximum value, while minimum value was found in water spray on PBM16 (Tables 18, 46).

4.1.1.9 Leaf fresh weight

Ethrel spray significantly affected plant fresh weight. The ethrel spray on the two cultivars was significant only at 80 DAS in Experiment 1 and non-significant in Experiment 2 (Tables 19, 47). Spray of 200µL/L ethrel gave highest value at all sampling times, while the minimum value was found with water-sprayed control.

Cultivar, Alankar, elicited maximum value as compared to PBM16. Interaction of ethrel spray and cultivar produced higher leaf fresh weight when spray of 200µL/L ethrel was done on Alankar, while the minimum value was found in water sprayed on PBM16.

4.1.1.10 Leaf turgid weight

Turgid weight of leaves was significantly affected by ethrel spray at all sampling times. Spray of ethrel on the two cultivars significantly differed at 80 DAS, whereas the two cultivars responded similarly to concentrations of ethrel in Experiment 2 (Tables 20, 48).

Spray concentration of 200µL/L ethrel showed maximum value at all sampling times in both the experiments At all sampling times, Alankar showed maximum value as compared to PBM16 in the two experiments.

Regarding interaction effect, it was observed that 200µL/L ethrel spray on Alankar expressed maximum effect. Minimum value was observed in water sprayed on PBM16.

4.1.1.11 Leaf relative water content

Relative water content in leaf significantly responded towards ethrel spray and for cultivars at all sampling stages in both the experiments. The interaction effect of these two was found significant at 80 DAS in Experiment 1 and at 80 and 100 DAS in Experiment 2 (Tables 21, 49).

Maximum value was recorded for 200µL/L ethrel at all growth stages and significantly minimum value was found in water sprayed control. Alankar showed higher values than PBM16 in both the experiments

Regarding the interaction between ethrel spray and cultivar, it was noted that 200µL/L ethrel spray on Alankar expressed the maximum value at 80 DAS in Experiment 1. Similarly, 200µL/L ethrel on Alankar proved best at 80 and 100 DAS in Experiment 2 (Tables 21, 49).

4.1.2 Physiological characteristics

4.1.2.1 Rate of photosynthesis

Rate of photosynthesis significantly reciprocated towards ethrel spray and for cultivar at all sampling stages. The interaction effect between ethrel spray and cultivar remained non-significant. Similar response was noted in both the experiments (Tables 22, 50).

Spraying concentration of 200µL/L ethrel gave maximum value at all sampling stages and significantly minimum value was found in water-sprayed control in both the experiments. Alankar showed higher value than PBM16 at all sampling times (Tables 22, 50).

4.1.2.2 Stomatal conductance

Stomatal conductance was significantly influenced by ethrel spray and cultivars differed significantly at all growth stages, but the interaction effect between ethrel spray and cultivar was non-significant (Tables 23, 51) in both the experiments.

Highest value for stomatal conductance was recorded with 200µL/L ethrel spray at all growth stages and significantly lowest value was found with water- sprayed control in Experiment 1 and Experiment 2. Alankar showed higher value than PBM16.

4.1.2.3 Internal CO_2 concentration

Effect of ethrel spray was significant on internal carbon dioxide concentration and cultivars also differed significantly at all sampling times. The interaction effect was non-significant (Tables 24, 52). A similar response was observed in both the experiments.

Maximum value for internal carbon dioxide concentration was noted with 200µL/L ethrel spray and Alankar exhibited higher values at all sampling times (Tables 24, 52).

4.1.2.4 Transpiration rate

In both the experiments, effect of ethrel spray and cultivar difference was significant at all growth stages, while the interaction effect between these two was found significant at 80 DAS (Tables 25, 53).

At all growth stages, 200µL/L ethrel spray gave maximum value. Significantly minimum value was recorded in water sprayed control. Alankar showed higher value as compared to PBM16 at all sampling stages.

Among various interactions, 200µL/L ethrel spray on Alankar expressed the maximum value. Significantly minimum value was given by water-sprayed control x PBM16 (Tables 25, 53).

4.1.2.5 Carboxylation efficiency

Effect of ethrel spray was found significant at all sampling times and cultivars differed significantly at 100 DAS in Experiment 1 and at all stages in Experiment 2. The interaction effect in both the experiments remained non-significant (Tables 26, 54).

Value recorded with 200µL/L ethrel spray was significantly maximum at all growth stages. Minimum value was recorded with water-sprayed control. Alankar showed maximum value as compared to PBM16 at all sampling stages.

4.1.2.6 Photosynthetic water use efficiency

Photosynthetic water use efficiency was significantly affected by ethrel spray and cultivars differed significantly at all growth stages. The interaction effect was significant at 80 DAS (Tables 27, 55) in both the experiments.

Spraying concentration of 200µL/L ethrel gave highest value at all growth stages. Significantly lowest value was found with water-sprayed control treatment. Value recorded for Alankar was significantly higher as compared to PBM16 at all growth stages.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray on Alankar gave maximum value and was at par with that for 200µL/L ethrel spray on PBM16 at 80 DAS. The effect was similar in both the experiments (Tables 27, 55).

4.1.2.7 Plant water use efficiency

Plant water use efficiency significantly reciprocated towards both ethrel spray and for cultivars difference at all sampling stages in the Experiment 1 and 2. The interaction effect was significant only at 80 DAS in Experiment 1 and non-significant in Experiment 2 (Tables 28, 56).

Values recorded for 200µL/L ethrel spray in Experiment 1 and 2 were significantly maximum at all growth stages and minimum values were found in water-sprayed control. Alankar proved better than PBM16.

Interaction effect of 200µL/L ethrel spray on Alankar registered higher water use efficiency, which differed critically from all other combinations.

4.1.3 Biochemical characteristics

4.1.3.1 N content

Nitrogen content in plant tissues significantly responded towards ethrel spray and cultivars also differed significantly at every sampling time in both the experiments. The interaction effect was found to be significant only at 80 DAS in Experiment 1 and at all sampling times in Experiment 2 (Tables 29, 57).

Spray of 200µL/L ethrel and Alankar registered maximum values at all sampling times in the two experiments. Water-sprayed control gave significantly minimum values.

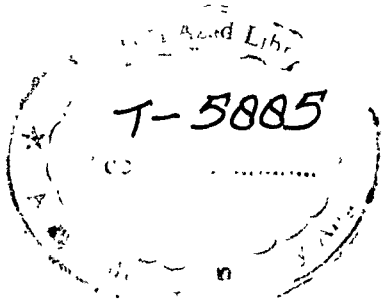
Among different interactions, 200µL/L ethrel spray on Alankar gave maximum value at 80 DAS in Experiment 1 but in Experiment 2, this interaction gave at par value with that for 200µL/L ethrel on PBM16 at 100 DAS.

4.1.3.2 N accumulation

Nitrogen accumulation was significantly influenced by both ethrel spray and for cultivars at all sampling times and the interaction effect was non-significant in Experiment 1. The interaction effect in Experiment 2 was significant at 80 and 100 DAS (Tables 30, 58).

Maximum value was recorded for 200µL/L ethrel spray at all sampling times. Significantly minimum value was found in water sprayed control. Alankar registered maximum value.

Interaction 200µL/L ethrel on Alankar proved best at 80 and 100 DAS in Experiment 2. The values differed significantly from other combinations (Tables 30, 58).



4.1.4 Yield characteristics

4.1.4.1 Number of pods per plant

Number of pods per plant was significantly affected by ethrel spray in Experiment 1 and 2. Similarly, in both the experiments, cultivars differed significantly. The interaction effect was non-significant in both the experiments (Tables 31, 59).

Significantly maximum value was recorded for 200µL/L ethrel spray, while the minimum value was found with water-sprayed control in both the experiments.

Among the cultivars, Alankar showed higher value as compared to PBM16 in both the experiments (Tables 31, 59).

4.1.4.2 Number of seeds per pod

Number of seeds per pod was significantly affected by both ethrel spray and cultivars. The interaction effect was non-significant (Tables 31, 59) in both the experiments.

Highest value for number of seeds per pod was recorded for 200µL/L ethrel spray. Significantly lowest value was found in water sprayed control in Experiment 1 and 2. Alankar showed higher value than PBM16 (Tables 31, 59).

4.1.4.3 1000 seed weight

Effect of ethrel spray and cultivar difference was found significant, while their interaction was found to be non-significant in both the experiments (Tables 31, 59).

Maximum value was recorded for 200µL/L ethrel spray. Significantly minimum value was noted in water sprayed control. Among the cultivars, Alankar showed higher value than PBM16 (Tables 31, 59). The response was similar in both the experiments.

4.1.4.4 Seed yield

Like yield attributes, seed yield was also significantly influenced by ethrel spray and cultivar difference was also significant. But interaction between these two remained non-significant. Similar response was noted in Experiment 1 and 2 (Tables 32, 60).

Spray concentration of 200µL/L ethrel gave significantly maximum value. Significantly lowest value was recorded for water sprayed control in both the experiments. Alankar gave higher value than PBM16 (Tables 32, 60).

4.1.4.5 Biological yield

Biological yield significantly responded towards both ethrel spray and the cultivar. The interaction effect between ethrel spray and cultivar was found non-significant in both the experiments (Tables 32, 60).

Significantly highest value was registered for 200µL/L ethrel spray, while the lowest value was found in water sprayed control in Experiment 1 and 2.

Value recorded for Alankar was significantly higher as compared to PBM16 in both the experiments (Tables 32, 60).

4.1.4.6 Harvest index

Harvest index was significantly influenced by both ethrel spray and cultivars, but no significant impact was observed when these two factors interacted (Tables 32, 60). Similar response was noted in Experiment 1 and 2.

Effect of ethrel spray at 200µL/L gave significantly maximum value. Significantly minimum value was recorded for water sprayed control treatment. Alankar showed more value for harvest index than PBM16 in Experiment 1 and 2 (Tables 32, 60).

4.1.4.7 Oil yield

Ethrel spray significantly affected oil yield. Cultivars also differed significantly. However, interaction effect was not significant in both the experiments (Tables 33, 61).

Maximum value was recorded for 200µL/L ethrel, which differed from other values recorded in other spray treatments in both the experiments. Alankar out yielded PBM16.

4.1.5 Quality characteristics

4.1.5.1 Oil content

Effect of ethrel spray was significant individually as well as on its effects on the cultivars. Cultivars also differed significantly for the oil content (Tables 33, 61) in Experiment 1 and 2.

Spray of 200µL/L ethrel registered significantly highest oil content in both the experiments. Cultivar Alankar proved better than PBM16. This resulted in maximum oil content in Alankar sprayed with 200µL/L ethrel than any other concentrations of ethrel on either cultivars in both the experiments (Tables 33, 61).

4.1.5.2 Acid value

Effect of ethrel spray and cultivar was significant in both the experiments. The interaction effect between these two was significant in Experiment 1 and non-significant in Experiment 2 (Tables 34, 62).

Ethrel at 200µL/L concentration gave significantly maximum value and Alankar registered highest acid value in both the experiments. Interaction of 200µL/L ethrel spray x Alankar registered higher acid value, which differed critically from all other combinations in Experiment 1 (Tables 34, 62).

4.1.5.3 Iodine value

Effect of ethrel spray, cultivar and their interaction effect were non-significant in the two experiments (Tables 34, 62).

4.1.5.4 Saponification value

Saponification value was significantly reciprocated to both ethrel spray and cultivar while the interaction effect between these two remained non-significant (Tables 34, 62). Similar response was noted in Experiment 1 and 2.

Spraying concentration of 200µL/L ethrel gave maximum value Significantly minimum value was noted for water sprayed control Alankar registered significantly higher value as compared to PBM16 (Tables 34, 62)

4.1.6 Pooled analysis of Experiment 1 and 2

Pooled analysis of the data of Experiments 1 and 2 was done to evaluate the performance of the cultivars in irrigated and non-irrigated conditions Also the impact of ethrel spray on the two cultivars under irrigated and non-irrigated experiments was evaluated (Tables 63, 71) The data showed that there was no significant effect of irrigation and cultivars also did not differ significantly under irrigated and non-irrigated conditions Similarly, ethrel spray was equally effective under the conditions of irrigation The three-way interaction was found non-significant

4.2 Experiment 3 and 4

Experiment 3 was conducted under irrigated conditions and Experiment 4 under non-irrigated conditions These experiments were conducted to investigate the effect of leaf-applied 0, 100 and 200µL/L ethrel (selected on the basis of Experiment 1 and Experiment 2) at 60d after sowing (DAS, flowering stage) on mustard (*Brassica juncea* L) cultivar Alankar grown with basally applied 0, 40, 60 or 80kg N/ha, on growth, physiological, biochemical, yield and quality characteristics determined at various sampling times as described in Experiment 1 and Experiment 2 Among physiological characteristics, 1-aminocyclopropane-1-carboxylic acid, ACC oxidase and ethylene evolution were also noted at 80 and 100 DAS samplings Among biochemical characteristics nitrate reductase activity was also recorded at 80 and 100 DAS samplings Among yield characteristics, seed nitrogen content per plant, nitrogen harvest index and nitrogen yield potential were also studied at harvest The details of the results are given below and summarized in Tables 72–137

4.2.1 Growth characteristics

4.2.1.1 Plant height

Plant height was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. However, the interaction effect between ethrel spray and nitrogen was found significant at 80 and 100 DAS in Experiment 3, and at 80 DAS in Experiment 4 (Tables 72, 105).

At all sampling times, 200µL/L ethrel spray showed significantly maximum value, while the minimum value was recorded in water-sprayed control in the two experiments.

Maximum height was recorded with 80kg N/ha and minimum with 0kg N/ha at all sampling times in both the experiments.

Among interactions, 200µL/L ethrel spray x 80kg N/ha proved best and gave significantly maximum value. Minimum value was recorded with water sprayed control x 0kg N/ha. This was the effect in both the experiments when the effect was significant (Tables 72, 105).

4.2.1.2 Plant leaf area

Leaf area was significantly affected by ethrel spray and nitrogen application at all sampling times in both the experiments, while their interaction effect was significant at all sampling times only in Experiment 3 (Tables 73, 106).

Maximum value was recorded with 200µL/L ethrel whereas minimum value was found with water-sprayed plants at all sampling times.

At all sampling times, treatment 80kg N/ha gave significantly maximum value, while the minimum value was registered with 0kg N/ha in both the experiments.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray x 80kg N/ha gave maximum value. Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 73, 108).

4.2.1.3 Leaf area index

Application of ethrel spray and nitrogen resulted into significant impact on leaf area index at all sampling times in both the experiments But the interaction effect between ethrel spray x nitrogen was significant at all sampling days in Experiment 3 only (Tables 74, 107)

Maximum and minimum values were recorded with 200µL/L ethrel spray and water-sprayed control respectively at all sampling times

At all sampling times, treatment 80kg N/ha gave significantly maximum value, whereas minimum value was recorded with 0kg N/ha in both the experiments

Interaction effect of ethrel spray and nitrogen produced higher leaf area index in combination of 200µL/L ethrel spray x 80kg N/ha Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 74, 107)

4.2.1.4 Specific leaf area

The effect of ethrel spray and nitrogen proved significant at all sampling times, while their interaction effect was found non-significant in both the experiments (Tables 75, 108)

At all sampling times, 200µL/L ethrel spray gave maximum value and minimum value was recorded with water-sprayed control in both the experiments

Application of nitrogen at 80kg N/ha exhibited maximum value and the minimum value was registered in 0kg N/ha at all sampling times in both the experiments (Tables 75, 108)

4.2.1.5 Specific leaf weight

Effect of ethrel spray and nitrogen was significant at all sampling times, while the interaction effect between these two was non-significant in both the experiments (Tables 76, 109)

At all sampling times, water-sprayed plants gave significantly maximum value, while the minimum value was recorded with 200µL/L ethrel spray

Treatment 0kg N/ha expressed maximum value, while the minimum value was recorded with 80kg N/ha at all sampling times in both the experiments (Tables 76, 109).

4.2.1.6 Plant dry weight

Ethrel spray and nitrogen significantly affected plant dry weight at all sampling times in both the experiments. The interaction effect between these two was significant at all sampling times in Experiment 3 only.

Maximum value was recorded with 200µL/L ethrel spray and minimum value with water-sprayed control at all sampling times in both the experiments.

At all sampling times, 80kg N/ha gave significantly maximum value, while the minimum value was recorded with 0kg N/ha.

Interaction effect of ethrel spray and nitrogen produced higher plant dry weight in the combination of 200µL/L ethrel x 80kg N/ha. Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 77, 110).

4.2.1.7 Dry weight of different plant parts

4.2.1.7.1 Leaf dry weight

Application of ethrel spray and nitrogen resulted in significant impact on leaf dry weight at all sampling times in both the experiments. The interaction between ethrel and nitrogen was significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, interaction effect was significant only at 120 DAS.

Maximum value was recorded with 200µL/L ethrel spray and minimum value with water-sprayed control at all sampling times in Experiment 3 and 4.

Application of nitrogen at 80kg N/ha gave significantly maximum value and differed from other treatments at all sampling times in Experiment 3 and 4.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray along with 80kg N/ha proved best compared to any other combinations in both the experiments (Tables 78, 111).

4.2.1.7.2 Stem dry weight

Effect of ethrel spray and basal nitrogen application was significant at all sampling times in Experiments 3 and 4. The interaction effect was significant at 120 DAS in Experiment 3, while in Experiment 4, interaction effect was significant only at 80 DAS (Tables 79, 112).

At all sampling times, 200µL/L ethrel showed maximum value, while minimum value was recorded with water-sprayed control in both the experiments.

Treatment 80kg N/ha exhibited maximum value and the minimum value was registered with 0kg N/ha at all sampling times in both the experiments.

Among interactions, 200µL/L ethrel x 80kg N/ha gave maximum value, while the minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 79, 112).

4.2.1.7.3 Pod dry weight

Pod dry weight was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments, while their interaction effect was significant at all sampling times in Experiment 3, and at 120DAS in Experiment 4 (Tables 80, 113).

Significantly maximum value was recorded with 200µL/L ethrel spray and minimum value was found with water-sprayed control at all sampling times in Experiments 3 and 4.

At all sampling times, treatment 80kg N/ha gave significantly maximum value, while the minimum value was recorded with 0kg N/ha in both the experiments.

Interaction between ethrel spray and nitrogen produced higher pod dry weight for the combination of 200µL/L ethrel spray x 80kg N/ha. Minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 80, 113).

4.2.1.8 Per cent distribution of dry weight in plant parts

4.2.1.8.1 Leaf

Effect of ethrel spray and nitrogen was significant at all sampling times in both the experiments. But the interaction effect between these two was significant at 80 and 100 DAS in Experiment 3 and at 120 DAS in Experiment 4 (Tables 81, 114)

At all sampling times, 200µL/L ethrel spray gave significantly maximum value, while the minimum value was recorded with water-sprayed control in both the experiments.

Application of nitrogen at 80kg N/ha gave significantly higher value, whereas the minimum value was registered with 0kg N/ha at all sampling times in Experiments 3 and 4.

Regarding the interaction effect, it was observed that 200µL/L ethrel x 80kg N/ha gave maximum value, which differed critically from other combinations in both the experiments (Tables 81, 114).

4.2.1.8.2 Stem

Effect of ethrel spray and application of nitrogen was significant at all sampling times in both the experiments. The interaction effect was significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, it was significant only at 120DAS (Tables 82, 115).

Water-sprayed plants and 200µL/L ethrel spray exhibited maximum and minimum values respectively at all sampling times in both the experiments.

At all sampling times, 0kg N/ha gave maximum value and minimum value was recorded with 80kg N/ha in Experiment 3 and 4.

Among interactions, water-sprayed control x 0kg N/ha showed maximum value, while minimum value was registered with 200µL/L ethrel x 80kg N/ha (Tables 82, 115).

4.2.1.8.3 Pod

Effect of ethrel spray and nitrogen was significant at all sampling times in Experiments 3 and 4. However, the interaction effect was significant at all sampling times in Experiment 3, whereas in Experiment 4, it was significant at 100 and 120 DAS (Tables 83, 116).

Highest per cent pod dry weight was recorded in 200µL/L ethrel spray, while minimum value was recorded in water sprayed control at all sampling times with both the experiments.

Application of 80kg N/ha resulted in significantly higher pod dry weight in both the experiments.

Regarding interaction effect, it was noted that 200µL/L ethrel x 80kg N/ha proved best and differed significantly from other combinations (Tables 83, 116) in both the experiments.

4.2.1.9 Leaf fresh weight

Leaf fresh weight was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. But the interaction between these two was found significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, it was significant at 120 DAS (Tables 84, 117).

Highest value of leaf fresh weight was recorded with 200µL/L ethrel spray, while the minimum value was found with water-sprayed control at all sampling times in both the experiments.

Application of nitrogen at 80kg N/ha showed significantly maximum value. Minimum value was recorded with 0kg N/ha at all sampling times in both the experiments.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray x 80kg N/ha proved best than any other combinations (Tables 84, 117) at sampling times when effect was significant.

4.2.1.10 Leaf turgid weight

Effect of ethrel spray and application of nitrogen was significant at all sampling times in both the experiments The interaction effect was significant at 80 and 100 DAS in Experiment 3, whereas in Experiment 4, it was significant only at 120 DAS

At all sampling times, 200µL/L ethrel showed significantly maximum value Minimum value was registered with water-sprayed control at both the experiments

At all sampling times, 80kg N/ha recorded maximum value and the minimum value was noted with 0kg N/ha

Among interactions, 200µL/L ethrel x 80kg N/ha gave maximum value, which differed significantly from other values Minimum value was recorded with water-sprayed control x 0kg N/ha (Tables 85, 118)

4.2.1.11 Leaf relative water content

Relative water content in leaf tissues was significantly affected by both ethrel spray and nitrogen at all sampling times in both the experiments However, the interaction effect between these two was found significant at 80 and 120 DAS only in Experiment 4 (Tables 86, 119)

Spray of 200µL/L ethrel gave significantly maximum value, whereas minimum value was recorded with water-sprayed control at all sampling times in both the experiments

At all sampling times, 80kg N/ha exhibited significantly maximum value, while minimum value was found with 0kg N/ha in both the experiments

Regarding the interaction effect, it was observed that 200µL/L ethrel spray x 80kg N/ha proved best as compared to any other combinations (Table 86, 119)

4.2.2 Physiological characteristics

4.2.2.1 Rate of photosynthesis

Effect of ethrel spray, nitrogen and their interactions were found significant at all sampling times in both the experiments (Tables 87, 120).

At all sampling times, 200µL/L ethrel spray gave significantly maximum value and the minimum value was recorded with water-sprayed control under

Application of nitrogen at 80kg N/ha gave maximum value, while minimum value was registered with 0kg N/ha at all sampling times in both the experiments

Among interactions, 200µL/L ethrel spray x 80kg N/ha gave maximum value and minimum value was given by water-sprayed control x 0kg N/ha (Tables87, 120)

4.2.2.2 Stomatal conductance

In Experiment 3 and 4, the effects of ethrel spray and nitrogen were significant, while their interaction effect was non-significant at all sampling times (Tables 88, 121).

At all sampling times, 200µL/L ethrel showed significantly maximum value, while the minimum value was recorded with water-sprayed control in Experiment 3 and Experiment 4

Treatment 80kg N/ha showed maximum value and the minimum value was registered with 0kg N/ha at all sampling times in both the experiments (Tables 88, 121).

4.2.2.3 Internal CO_2 concentration

Effects of ethrel spray and nitrogen were significant at all sampling times in both the experiments. The interaction effect was significant at all sampling times in Experiment 3, whereas in Experiment 4, it was significant only at 80 DAS (Tables 89, 122).

Maximum value was recorded with 200µL/L ethrel, which differed critically from other values and the minimum value was found with water-sprayed control at all sampling times in both the experiments

At all sampling times, application of nitrogen at 80kg N/ha gave maximum value, while the minimum value was recorded with 0kg N/ha

Regarding the interaction effect, it was observed that 200µL/L ethrel x 80kg N/ha proved best, when compared to any other combinations (Tables 89, 122)

4.2.2.4 Transpiration rate

Rate of transpiration was significantly responded towards both ethrel spray and nitrogen at all sampling times in both the experiments. However, the interaction effect was significant at all sampling times in Experiment 3, whereas in Experiment 4, it was significant only at 100 DAS (Tables 90, 123)

Maximum transpiration rate was recorded with 200µL/L ethrel spray, while minimum value was recorded in water-sprayed control at all sampling times

At all sampling times, treatment 80kg N/ha gave significantly maximum value and minimum value was registered with 0kg N/ha in both the experiments.

Regarding the interaction effect, it was observed that 200µL/L ethrel spray x 80kg N/ha gave maximum value. Minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 90, 123).

4.2.2.5 Carboxylation efficiency

Application of ethrel spray and nitrogen resulted in significant impact on carboxylation efficiency at all sampling times in both the experiments. But the interaction effect between ethrel spray and nitrogen was significant at 100 DAS in Experiment 4, whereas in Experiment 3, the interaction effect was non-significant (Tables 91, 124).

At all sampling times, 200µL/L ethrel spray gave significantly maximum value. Minimum value found in water-sprayed control at all sampling times in both the experiments.

At all sampling times, treatment 80kg N/ha showed significantly maximum value, while the minimum value was noted with 0kg N/ha in both the experiments.

Among interactions, 200µL/L ethrel x 80kg N/ha gave significantly maximum value and minimum value was recorded with water-sprayed control x 0kg N/ha in Experiment 4 at 100 DAS (Tables 91, 124).

4.2.2.6 Photosynthetic water use efficiency

Effect of ethrel spray and application of nitrogen were significant at all sampling times in both the experiments. The interaction effect was significant only at 80 DAS in Experiment 3, and at both stages (80 and 100 DAS) in Experiment 4 (Tables 92, 125).

In Experiment 3 and 4, greatest values for photosynthetic water use efficiency were recorded with 200µL/L ethrel spray treatment at both sampling time and minimum value was noted in water-sprayed control.

Treatment 80kg N/ha showed maximum values at both sampling times in the two experiments. Significantly maximum value was given by 200µL/L ethrel x 80kg N/ha, while minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 92, 125).

4.2.2.7 Plant water use efficiency

Plant water use efficiency was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. The interaction effect between ethrel spray and nitrogen was significant at 80 DAS in Experiment 4 (Tables 93, 126).

At all sampling times, 200µL/L ethrel spray resulted in significantly maximum value and the minimum value was recorded with water-sprayed control.

Treatment 80kg N/ha gave significantly maximum value, while the minimum value was recorded with 0kg N/ha at all sampling times in both the experiments.

Among interactions, plant water use efficiency was affected by ethrel spray at 200µL/L concentration along with 80kg N/ha (Tables 93, 126).

4.2.2.8 ACC content

1-aminocyclopropane-1-carboxylic acid content was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. The interaction effect between ethrel spray and nitrogen was significant at 100 DAS in Experiment 3, and at all sampling times in Experiment 4 (Tables 94, 127). A concentration of 200µL/L ethrel showed maximum value at all sampling times. Among applied nitrogen levels, 80kg N/ha gave significantly maximum value and the minimum value was recorded with 0kg N/ha at all sampling times in both the experiments.

Regarding the interaction effect, it was observed that 200µL/L ethrel sprayed on plants grown with basal 80kg N/ha registered maximum value in both the experiments (Tables 94, 127).

4.2.2.9 ACC oxidase

Application of ethrel spray and nitrogen resulted in significant impact on ACC oxidase at all sampling times. The interaction effect was significant at 80 DAS in Experiment 3 and at 100 DAS in Experiment 4 (Table 95, 128).

Spray of 200µL/L ethrel and water spray gave significantly maximum and minimum values respectively at all sampling times in both the experiments. Application of nitrogen at 80kg N/ha resulted in maximum value and minimum value was registered with 0kg N/ha at all sampling times in both the experiments (Tables 95, 128).

Among interactions, 200µL/L ethrel x 80kg N/ha proved best, when compared to any other combinations (Tables 95, 128).

4.2.4.10 Ethylene evolution

Ethrel spray and nitrogen significantly affected the ethylene evolution at all sampling times in both the experiments. The interaction effect between these two was significant at 80 DAS in Experiment 4 (Tables 96, 129).

Ethylene evolution increased with increase in ethrel spray at both sampling times in the two experiments. Similarly, increase in nitrogen levels increased ethylene evolution. Such effect was seen in spray of 200µL/L ethrel on plants grown with 80kg N/ha, which showed significantly maximum value (Tables 96, 129).

4.2.3 Biochemical characteristics

4.2.3.1 Nitrate reductase activity

Nitrate reductase activity in leaf tissues was significantly affected by ethrel spray and nitrogen at all sampling times in both the experiments. But the interaction effect between ethrel spray and nitrogen was non-significant in both the experiments (Tables 97, 130).

Spray of 200µL/L ethrel and water spray gave significantly maximum and minimum values respectively at all sampling times.

Application of nitrogen at 80kg N/ha resulted in maximum value and minimum value was registered with 0kg N/ha at all sampling times in both the experiments (Tables 97, 130).

4.2.3.2 N content

Nitrogen content in plant tissues significantly responded towards both ethrel spray and levels of nitrogen at all sampling stages in both the experiments. The interaction effect was significant at 80 DAS and 120 DAS in Experiment 3 and at 80 DAS in Experiment 4 (Tables 98, 131).

Spray of 200µL/L ethrel showed significantly maximum value at all sampling times. Among applied nitrogen levels, 80kg N/ha showed significantly maximum values at all sampling times in both the experiments.

Among interactions, 200µL/L ethrel x 80kg N/ha gave significantly maximum value and minimum value was recorded with water-sprayed control x 0kg N/ha in both the experiments (Tables 98, 131).

4.2.3.3 N accumulation

Nitrogen accumulation was significantly affected by ethrel spray and nitrogen at all sampling times. The interaction effect was significant at 80 and 100 DAS in Experiment 3 and at 80 and 120 DAS in Experiment 4 (Tables 99, 132).

At all sampling times, 200µL/L ethrel spray gave significantly maximum value, while the minimum value was recorded with water-sprayed control.

Application of nitrogen at 80 and 0kg N/ha showed significantly maximum and minimum values respectively at all sampling times in both the experiments.

Regarding the interaction effect, it was observed that accumulation of nitrogen was significantly affected by 200µL/L ethrel x 80kg N/ha (Tables 99, 132).

4.2.4 Yield characteristics

4.2.4.1 Number of pods per plant

Ethrel spray and nitrogen significantly affected pod number in both the experiments. The interaction effect between ethrel spray and nitrogen was non-significant in both the experiments (Tables 100, 133).

Ethrel spray at 200µL/L concentration and water spray resulted in significantly maximum and minimum values respectively. Basal 80kg N/ha proved best for pod number in both the experiments (Tables 100, 133).

4.2.4.2 Number of seeds per pod

Number of seeds per pod was significantly influenced by ethrel spray and nitrogen in both the experiments and the interaction effect was significant in Experiment 4 (Tables 100, 133).

Individual as well as combined effect of 200µL/L ethrel spray and 80kg N/ha proved superior than any other treatments (Tables 100, 133).

4.2.4.3 1000 seed weight

The seed weight was also significantly affected by ethrel spray and nitrogen in both the experiments, proving 200µL/L ethrel and 80kg N/ha most effective (Tables 100, 133).

4.2.4.4 Seed yield

Seed yield of the crop was significantly affected by ethrel spray and nitrogen, but their interaction effect was non-significant in both the experiments (Tables 101, 134).

Seed yield was significantly maximum in 200µL/L ethrel concentration and 80kg N/ha, while the minimum value was noted with water-sprayed control in both the experiments (Tables 101, 134).

4.2.4.5 Biological yield

Biological yield was significantly influenced by ethrel spray and nitrogen in both the experiments. But the interaction effect between these two was found significant only in Experiment 3 (Tables 101, 134).

Concentration of 200µL/L ethrel spray and 80kg N/ha individually and interactively gave maximum value and the minimum value was registered with water-sprayed control (Tables 101, 134).

4.2.4.6 Harvest index

Individual and combined effect of ethrel spray and nitrogen were found significant in both the experiments (Tables 101, 134).

Significantly maximum value was recorded with 200µL/L ethrel spray and 80kg N/ha and their interaction in both the experiments (Tables 101, 134).

4.2.4.7 Oil yield

Application of ethrel spray and nitrogen resulted in significant impact on oil yield. But the interaction effect was non-significant (Tables 103, 136).

Maximum value was recorded with 200μL/L ethrel and the minimum value was noted with water-sprayed control in both the experiments.

Application of nitrogen at 80kg N/ha showed maximum value, while the minimum value was recorded with 0kg N/ha (Tables 103, 136).

4.2.4.8 Seed nitrogen per plant

Effect of ethrel spray, nitrogen and their interaction were found to be significant in both the experiments (Tables 102, 135).

Among ethrel treatments, 200μL/L ethrel spray gave maximum value and the minimum was found with water-sprayed control in both the experiments.

Among applied nitrogen levels, 80kg N/ha registered highest value while control recorded significantly lowest value.

Regarding the interaction effect, it was observed that 200μL/L ethrel spray x 80kg N/ha proved best in comparison to any other combinations (Tables 102, 135).

4.2.4.9 Nitrogen harvest index

Nitrogen harvest index was non-significant for ethrel spray, applied nitrogen and their interaction (Tables 102, 135).

4.2.4.10 Nitrogen yield potential

Effect of ethrel spray application, levels of nitrogen and their interaction effect were found significant in both the experiments (Tables 102, 135).

Highest nitrogen yield potential was recorded with 200μL/L ethrel spray and the minimum value was found with water-sprayed control.

Application of nitrogen at 80kg N/ha gave maximum value and the minimum value was recorded with 0kg N/ha in both the experiments.

Among interactions, 200μL/L ethrel spray x 80kg N/ha gave significantly maximum value, while the minimum value was registered with water-sprayed control x 0kg N/ha (Tables 102, 135).

4.2.5 Quality parameters

4.2.5.1 Oil content

Effect of ethrel spray was significant, while the effect of nitrogen and interaction effect was non-significant in both the experiments (Tables 103, 136)

Ethrel spray increased oil content and 200µL/L proved most effective in both the experiments (Tables 103 136)

4.2.5.2 Acid value

Effect of ethrel spray was significant, while nitrogen effect and their interaction effect was non-significant (Tables 104, 137)

Spray of 200µL/L ethrel showed maximum value, while the minimum was recorded with water-sprayed control (Tables 104, 137)

4.2.5.3 Iodine value

Effect of ethrel spray only was significant in both the experiments (Tables 104, 137) Maximum iodine value was recorded with 200µL/L ethrel

4.2.5.4 Saponification value

Saponification value was significantly affected by ethrel spray, while nitrogen and the interaction effect was found non-significant in both the experiments (Tables 104, 137)

Concentration of 200µL/L ethrel spray gave maximum value and the minimum value was recorded with water-sprayed control in both the experiments (Tables 104, 137)

4.2.6 Pooled analysis of Experiment 3 and 4

Pooled analysis of the data of Experiments 3 and 4 was done to evaluate the effect of ethrel spray and nitrogen application under irrigated and non-irrigated conditions (Tables 138–146) Irrigation did not significantly affect the characteristics studied The nitrogen application and ethrel spray under irrigated and non-irrigated conditions were equally effective The three-way interaction was found non-significant

4.3 Experiment 5

This experiment was conducted to confirm the effects of 200µL/L ethrel spray (reported in Experiments 1–4) on growth, physiological, biochemical, yield and quality characteristics of mustard grown under irrigated and non-irrigated conditions. For this, plants were grown with uniform basal dose of 80kg N/ha and were sprayed with either 0, 200µL/L ethrel or 1mM of silver thiosulphate (STS; a ethylene action inhibitor) at 60d after sowing (DAS; flowering stage). Growth of the plants was assessed for plant leaf area and plant dry weight, whereas other characteristics studied were similar as in Experiment 3 and Experiment 4. The details of the results are given below and summarised in Tables 147–166.

4.3.1 Growth characteristics

Spray significantly affected the plant leaf area and plant dry weight at all sampling times. The effect of spray under irrigated and non-irrigated plants for these two characteristics was similar (Tables 147, 148). Highest plant dry weight was recorded with 200µL/L ethrel spray, but the plants sprayed with silver thiosulphate (STS) showed lowest plant dry weight.

4.3.2 Physiological characteristics

Among the physiological characteristics studied, spray of 200µL/L ethrel enhanced the traits in comparison to no ethrel spray. However, spray of silver thiosulphate (1mM) reduced the effects of ethrel spray and value decreased to lower than the control.

Irrigation effect and interaction of spray with irrigation were non-significant. Similar results were observed for the photosynthetic rate, stomatal conductance, internal CO_2 concentration, carboxylation efficiency, photosynthetic water use efficiency, plant water use efficiency, 1-aminocyclopropane carboxylic acid content, ACC oxidase and ethylene evolution (Tables 149–158).

4.3.3 Biochemical characteristics

Nitrate reductase activity, nitrogen content and nitrogen accumulation were significantly affected by spray Ethrel spray enhanced nitrogen content and accumulation in plants compared with no ethrel spray Silver thiosulphate spray decreased these contents Under irrigated and non-irrigated conditions, spray of ethrel was equally effective (Tables 159–161)

4.3.4 Yield characteristics

Number of pods and seeds, 1000 seed weight, seed yield, biological yield, harvest index, oil yield, seed nitrogen content per plant and nitrogen yield potential were significantly increased by 200µL/L ethrel spray Silver thiosulphate spray confirmed the positive effect of ethylene as ethrel spray (Tables 162–164)

4.3.5 Quality characteristics

Quality assessed in terms of oil content, acid, iodine and saponification values were significantly affected by 200µL/L ethrel spray Spray effects under irrigated conditions did not differ significantly (Tables 165–166)

CHAPTER–5
DISCUSSION

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DISCUSSION

DISCUSSION

5.1 Introduction

The efforts to increase land productivity have increased due to expanding food demand because of population explosion and decreasing land-man ratio. In post-independent India a new surge began in the shape of well known 'Green Revolution', which became meaningless after five decades due to non-sustainable food production for the ever-increasing population. The task of Green Revolution was achieved through the use of chemical fertilizers, one of the several factors With this chemical fertilizer tool, although food grain production in the country was achieved but its use also resulted in problems of soil salination, ground water pollution, nutrient imbalance, emergence of new pest diseases and environmental degradation. The problem further aggravates by the constant rise in population, which is estimated that by 2020, India's population is likely to be around 1.3 billion. In addition to this, All India Yield Indices of Major Crops is found to be stagnating or decreasing due to stagnating yield and decreasing land-man ratio. This has exerted a massive pressure for managing the available resources in such a way as to be benefited maximally through environmentally sustainable techniques. Nitrogen is one of the mineral nutrient elements of prime importance in increasing crop productivity. It has a well-established role in the crop plants and is taken up in large quantity by plants. It is estimated that terrestrial plants assimilate approximately 1.4 gigatons of nitrogen annually and about 90 to 95% of the total in form of mineral nitrogen (Marschner, 1986). Although more input of nitrogen increases growth and yield of the crops, but its excessive use causes environmental degradation phenomenon like eutrophication of the resources.

Therefore, an approach is to be explored which minimizes the use of nitrogen without decreasing the growth and yield of crops. In this context, use of plant hormones may prove its potential as it has been found to enhance

growth and productivity of the crop plants (Leopold and Kriedmann, 1979; Khan, 1996a; Singh, 1996; Khan *et al.*, 1997; Khan *et al.*, 2000; 2001). Of several naturally occurring phytohormones, ethylene influences about all aspects of plant growth and development (Mattoo and White, 1991; Abeles *et al.*, 1992) as well as the induction of some plant defence responses (Boller, 1991). Ethylene produced in trace amount elicits many physiological responses, acting at a concentration as low as 0.01μL/L (Reid, 1987). Ethylene releasing compounds are applied to cereal crops to prevent lodging, thereby reducing yield losses and deterioration of grain quality (Foster *et al.*, 1991; Moes and Stobbe, 1991a, b), and to mustard for increasing yield (Khan, 1996b; Khan *et al.*, 2000).

Keeping in view the above facts, five field trials were conducted on mustard (*Brassica juncea* L. Czern & Coss.) on the following lines:

1. To study the effect of ethrel spray on growth, physiological, biochemical, yield and quality characteristics of mustard cultivars under irrigated and non-irrigated conditions.
2. To study the effect of ethrel spray on mustard grown with nitrogen levels under irrigated and non-irrigated conditions for nitrogen use efficiency and yield of the crop.
3. To test the hypothesis that ethylene has a central role in mediating plant responses with the use of ethylene action inhibitor silver thiosulphate

The results obtained in Chapter 4 are discussed below:

5.2 Comparison of Cultivars

In Experiment 1 and 2, Alankar and PBM16 cultivars of mustard (*Brassica juncea* L.) were used as experimental material. The rationale for use of the two cultivars is given in Materials and Methods section. The two cultivars responded similarly to ethrel application, giving maximal response with 200μL/L ethrel concentration. Both the cultivars showed inhibitory response to spray of ethrel higher than 200μL/L concentration.

For almost all growth characteristics, Alankar registered higher values than PBM16. Increase in inter-nodal length in Alankar was reflected in taller plants than PBM16. Leaf growth (area) in Alankar was more than PBM16 because of massive and irreversible expansion of daughter cell by meristematic divisions (Fig. 4). Also, Alankar showed higher inherent efficiency of retaining more moisture content in leaf tissues than PBM16. This was reflected in higher values for leaf fresh weight, leaf turgid weight and leaf relative water content (Tables 19, 47, 20, 48, 21, 49). Since leaf expansion is associated with trapping of solar energy and production of dry matter, therefore, Alankar registered higher dry weight (Fig. 6), and per cent distribution of dry weight towards leaf and pod (on emergence) was more in Alankar than PBM16. Thus, the efficiency of Alankar for translocating photoassimilates from leaf (source) to pod (sink) was greater than PBM16.

Alankar with large canopy structure, helped in efficiently receiving photosynthetically active radiation resulting in higher rate of net photosynthesis (Fig. 5) than PBM16. Higher leaf surface area as mentioned earlier was due to enhanced number of cell division and cell expansion. Increase in internal CO_2 concentration and stomatal conductance were reflected in more carboxylation efficiency, photosynthetic water use efficiency and water use efficiency in Alankar (Tables 26, 54, 27, 55, 28, 56).

The high efficiency of Alankar for conversion of biological matter to seed resulted in higher number of pods and seed yield (Fig. 7). The main contributing factor for increase in seed yield was pod number and seed number and 1000 seed weight was found almost equal in the two cultivars. Together with higher seed yield, oil yield of Alankar was more because of higher oil content than PBM16 (Tables 32, 60, 33, 61). It may be mentioned here that Alankar is the most suited cultivar grown in the region and surpassed other cultivars so far released. The cultivar was found equally suitable for irrigated and non-irrigated conditions.

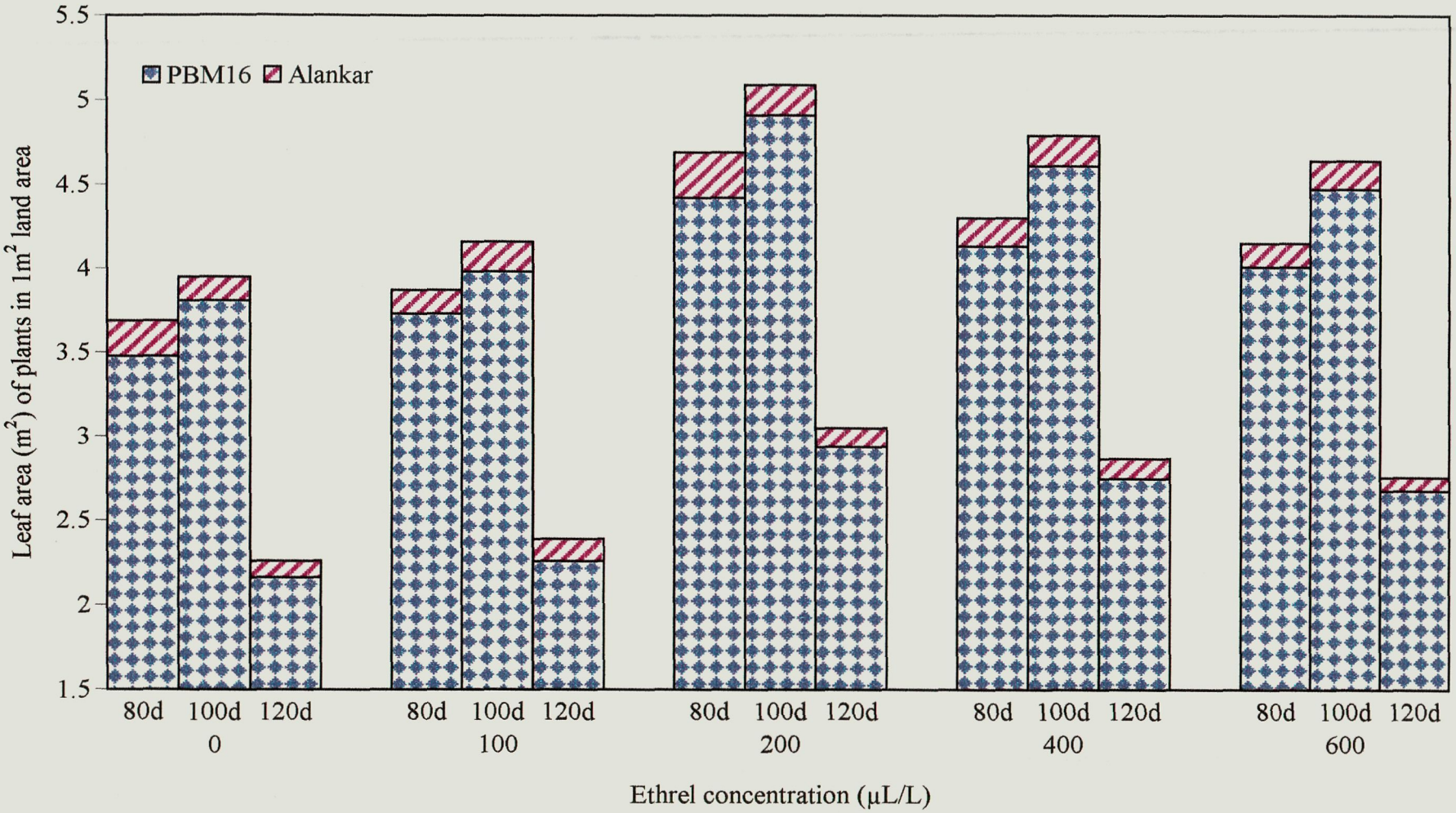


Fig. 4. Effect of ethrel spray on leaf area of Alankar and PBM16 cultivars of mustard (*Brassica juncea* L.)

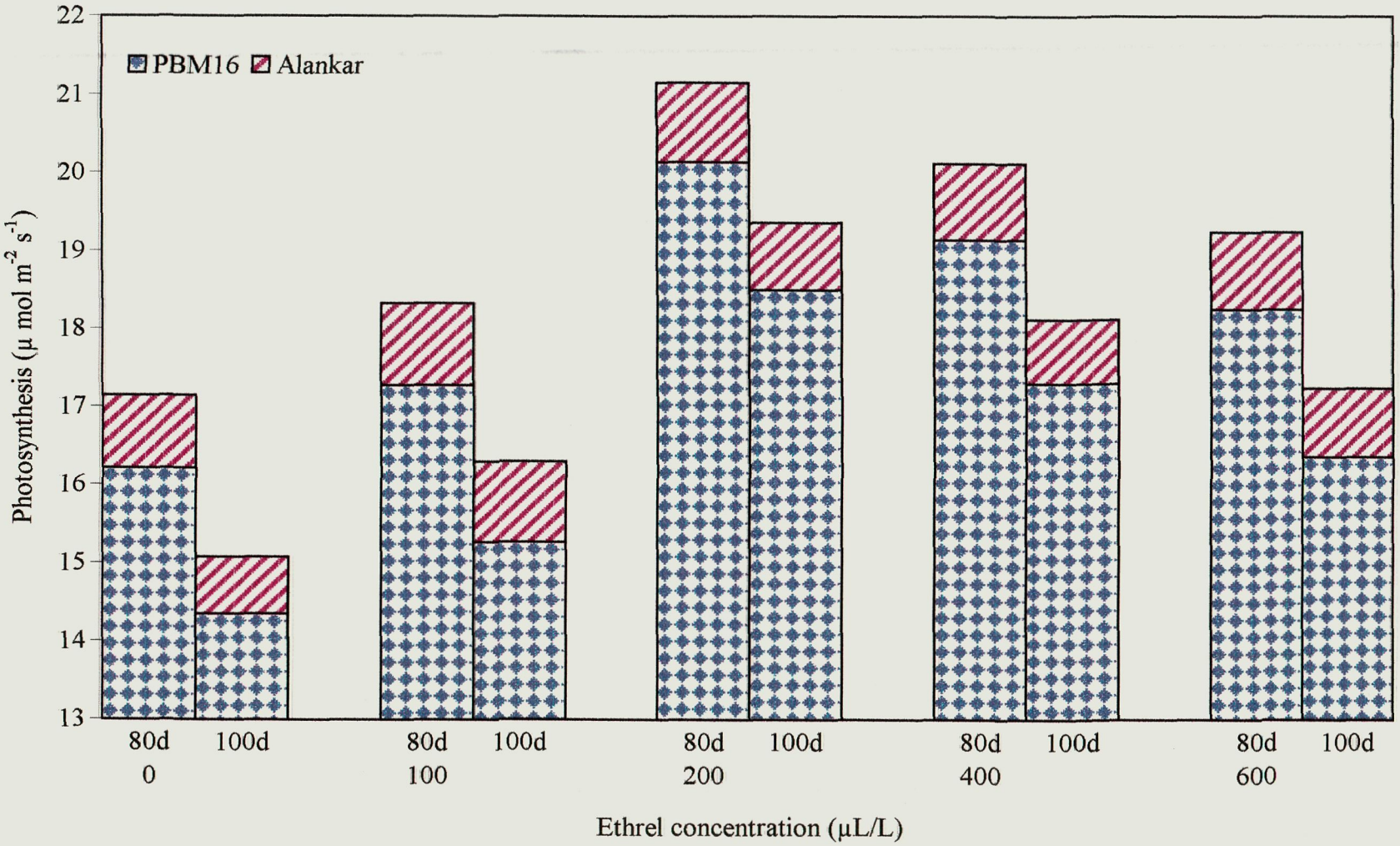
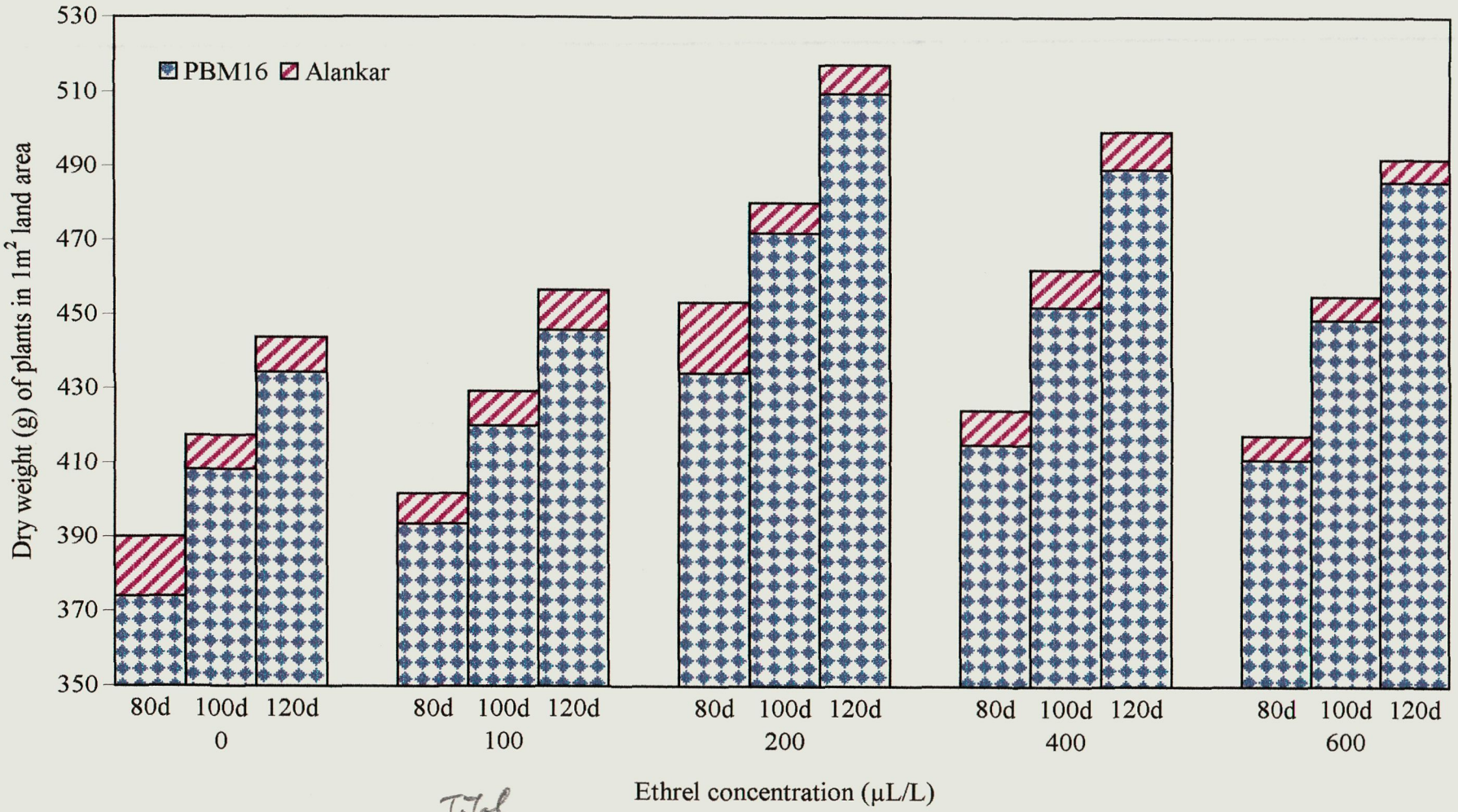


Fig. 5. Effect of ethrel spray on net photosynthetic rate of Alankar and PBM16 cultivars of mustard (*Brassica juncea* L.)



Total

Fig. 6. Effect of ethrel spray on dry weight of Alankar and PBM16 cultivars of mustard (*Brassica juncea* L.)

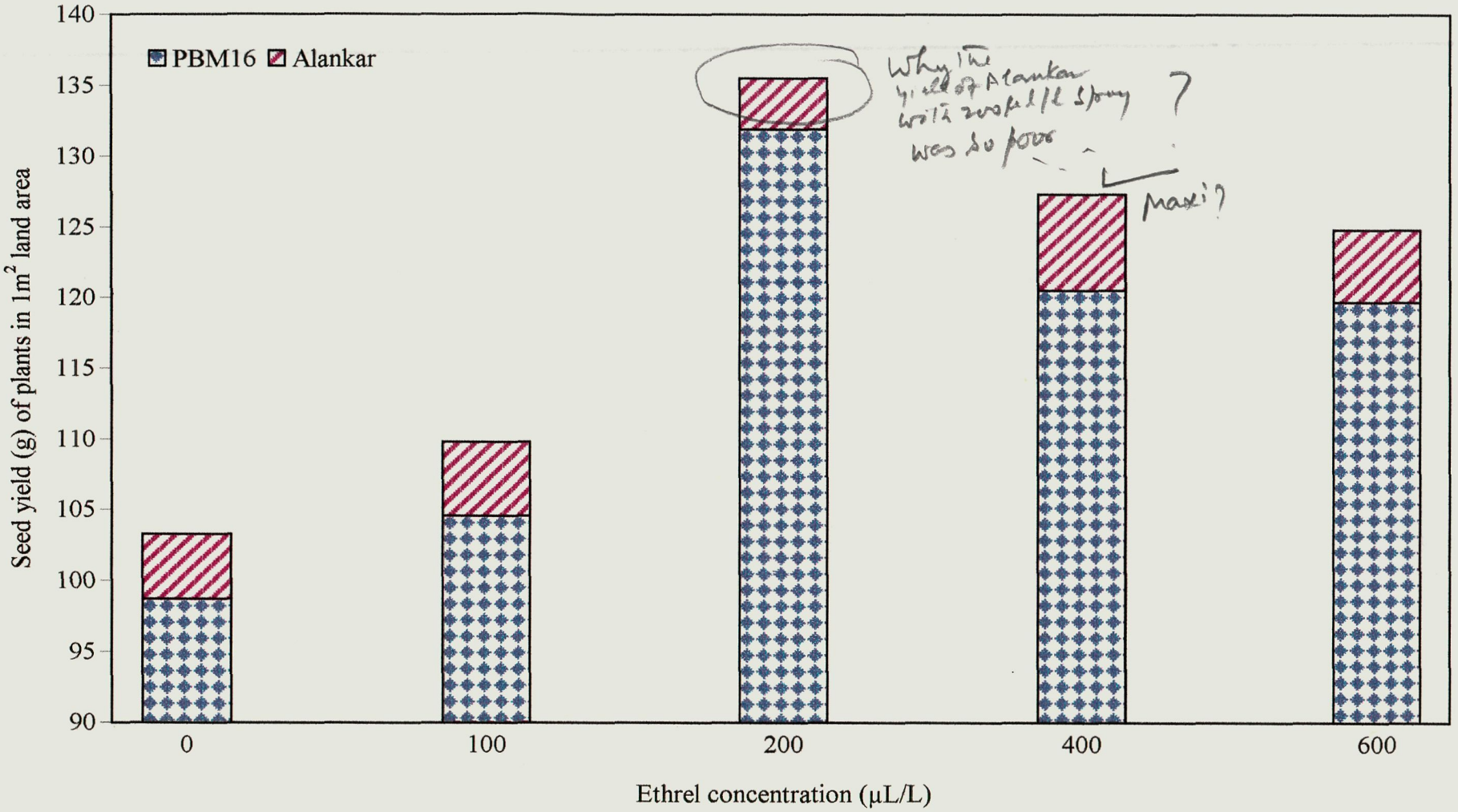


Fig. 7. Effect of ethrel spray on seed yield of Alankar and PBM16 cultivars of mustard (*Brassica juncea* L.)

5.3 Effects of ethrel, a ethylene releasing compound

It is mentioned in Material and Methods section that Experiment 1 and 3 were conducted under irrigated conditions and Experiment 2 and 4 under non-irrigated conditions The response of the crop to ethrel and nitrogen application was similar under these conditions of availability of water This was possibly due to fact that mustard is a harder crop as moisture availability is concerned and may be said as drought tolerant Moreover, monsoon showers during the month of December, when there is a higher need of moisture for reproductive parts formation, meet the water requirement Therefore, the crop behaved similarly under irrigated and non-irrigated conditions, although with a difference in the absolute values for the plant characteristics In the following pages, attempt has been made to discuss the results obtained in experiments with an assumption that similar phenomenon occurred due to the effect of ethrel or nitrogen under irrigated and non-irrigated conditions

5.3.1 Growth characteristics

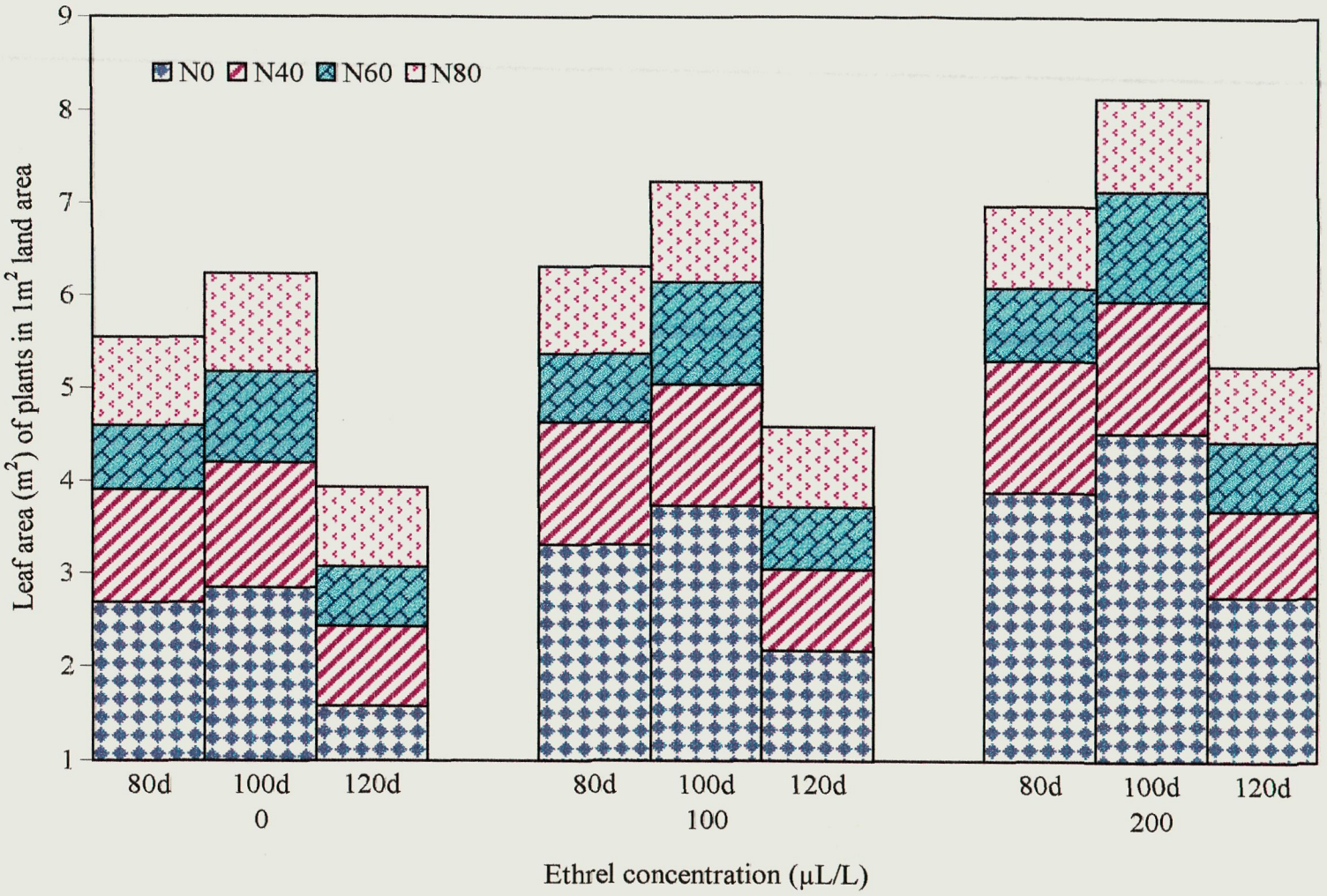
Spray of 200µL/L ethrel increased growth characteristics maximally in Experiments 1-4 Further increase in ethrel concentration (400 to 800µL/L) proved inhibitory Plant heights in Experiment 1 and 2 were increased by 14 9 and 16 2% respectively due to 200µL/L ethrel application Such increasing effects of ethrel are basically on internode growth of plants (Sisler and Yang, 1984) Contrasting effects of ethylene sources on plant height have been reported in different plant species For example, increased plant height in cauliflower (Jana and Kabir, 1991) due to ethrel application has been found Contrarily, higher concentrations of ethrel/ethephon reduced plant height in sunflower (Sauerbrey *et al*, 1988), winter wheat (Van Sanford *et al.*, 1989), radish (Vreugdenhill and Harro, 1989), lupin (Ortuno *et al*, 1993), arabidopsis seedlings (Smalle *et al*, 1997), barley (Sanvicente *et al.*, 1999) linseed (Leitch and Kuat, 1999) and barley, oat and wheat (Rajala and Peltonen-Sainio, 2001) Wherever reduction of plant height was observed, this was due to use of higher

concentrations of ethrel In this study also, higher concentrations of ethrel (400–800µL/L) reduced plant height These conflicting observations involved several mechanisms Firstly, ethylene is found to promote the reorientation of cortical microtubules, thereby possibly controlling elongation (Shibaoka, 1994) Secondly, a role for ethylene has been suggested in regulating the expression of cell wall peroxidase involved in the control of the wall extensibility and cell growth (Ridge and Osborne, 1971) Regulating the levels of peroxidase activity by suitable concentration of ethrel possibly influenced the direction of growth of active tissues and organs This effect of ethrel led to the emergence and formation of leaves with enhanced total leaf area of plant Lower concentration of ethrel (200µL/L) produced maximum leaf area, giving 27 0 and 35 7% increases over control in Experiment 1 and 2 respectively and higher concentration reduced the leaf area (Tables 8, 36, Fig 4) Similar observation has been reported by Lee and Reid (1997) in sunflower Ivenish and Kreicbergs (1992), in cereal seedlings, reported that leaf emergence is associated with a peak of ethylene evolution A similar phenomenon has been observed in *Arabidiopsis* and burst of ethylene was accompanied by an increased expression of the ACC synthase gene 1, a gene suggested to be involved in the control of cell expansion (Rodrigues-Pousida *et al*, 1993) Thus, the induction of ethylene biosynthesis as in this may be associated with leaf emergence or in the control of cell expansion This is also supported from the studies on ethylene-insensitive mutants, which have a large rosette than the wild type (Ecker, 1995) resulting from cell enlargement (Hua *et al*, 1995) Leaf fresh weight, leaf turgid weight, leaf relative water content and plant dry weight were significantly increased by 200µL/L ethrel (Tables 19, 47, 20, 48, 21, 49, 12, 40) because of observed increase in water use efficiency and photosynthetic water use efficiency in this ethrel treatment (Tables 27, 55, 28, 56) These aspects of efficiency parameters have been discussed in the following pages under a separate heading Physiological characteristics (Section 5 3 2)

It was found that the distribution of dry weight (on per cent basis) towards pods was higher in 200µL/L ethrel-sprayed plants. The dry weight thus accumulated was efficiently translocated to pod causing increase in per cent pod dry weight (Tables 18, 46). Linear regression analysis for various growth parameters with seed yield for Experiments 1–4 (Tables 167–178) also confirms the contribution of growth characteristics in yield.

Experiments 3 and 4 were conducted to assess the efficacy of foliar spray of ethrel on plants grown with nitrogen levels under irrigated (Experiment 3) and non-irrigated conditions (Experiment 4). Nitrogen is a major limiting nutrient for most plant species (Greenwood, 1982). Acquisition and assimilation of nitrogen is second in importance only to photosynthetic carbon assimilation for plant growth and development (Heickel, 1980; Araus *et al.*, 1993; Anten *et al.*, 1995; Arthamawar *et al.*, 1996). Non-availability of nitrogen in Experiment 3 and 4 affected growth characteristics (Tables 72–86, 105–119). The best dose of nitrogen was 80kg N/ha and nitrogen level lower than this showed poor growth. At low (0 to 60kg N/ha) nitrogen level, the N absorbed by the roots was utilized for protein synthesis from reserve root carbohydrates and supply of N to the top of plants was limited affecting the growth of the shoot. The lesser N content present in the plant (Tables 98, 131, 99, 132) also show that at lower levels of basally applied N, the plant growth was poor and not benefited much.

In this study the growth response of the plant was maximum with application of 80kg N/ha together with spray of 200µL/L ethrel. The values obtained for this combination were maximum and higher than any other combinations of nitrogen and ethrel concentration (Fig. 8–15). The positive effect of 200µL/L ethrel spray together with 80kg N/ha is attributed to the changes in ethylene evolution (discussed in section 5.3.2). The ethylene evolution is reported to be increased by excessive ammonia accumulation (Corey *et al.*, 1987; Arshad and Frenkenberger, 1991) and can be induced by



The actual value of effect of N level is difficult to note

Fig. 8. Effect of ethrel spray on leaf area of cultivar Alankar of mustard (*Brassica juncea* L.) grown with different levels of nitrogen

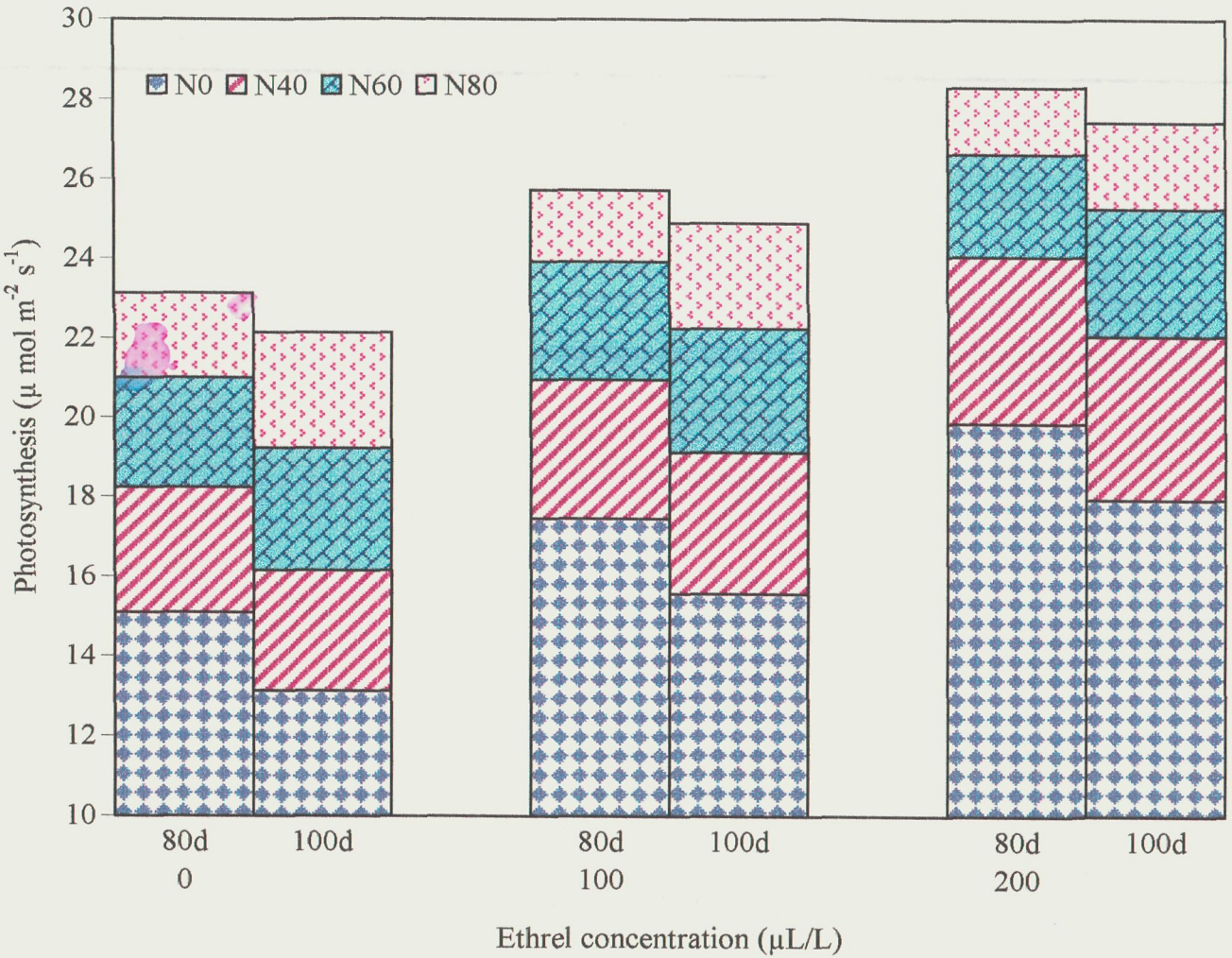


Fig. 9. Effect of ethrel spray on net photosynthetic rate of cultivar Alankar of mustard (*Brassica juncea* L.) grown with different levels of nitrogen

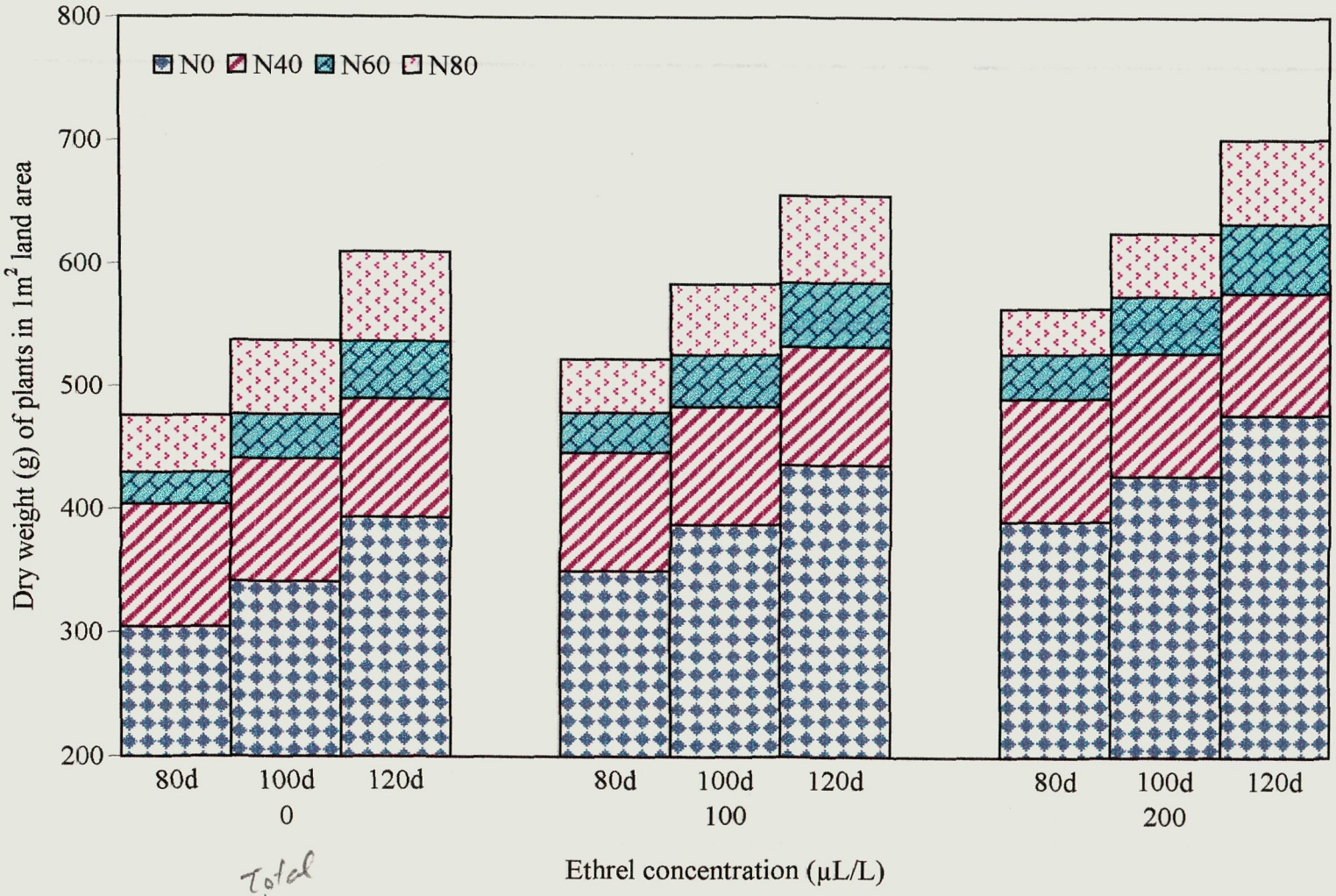


Fig. 10. Effect of ethrel spray on total dry weight of cultivar Alankar of mustard (*Brassica juncea* L.) grown with different levels of nitrogen

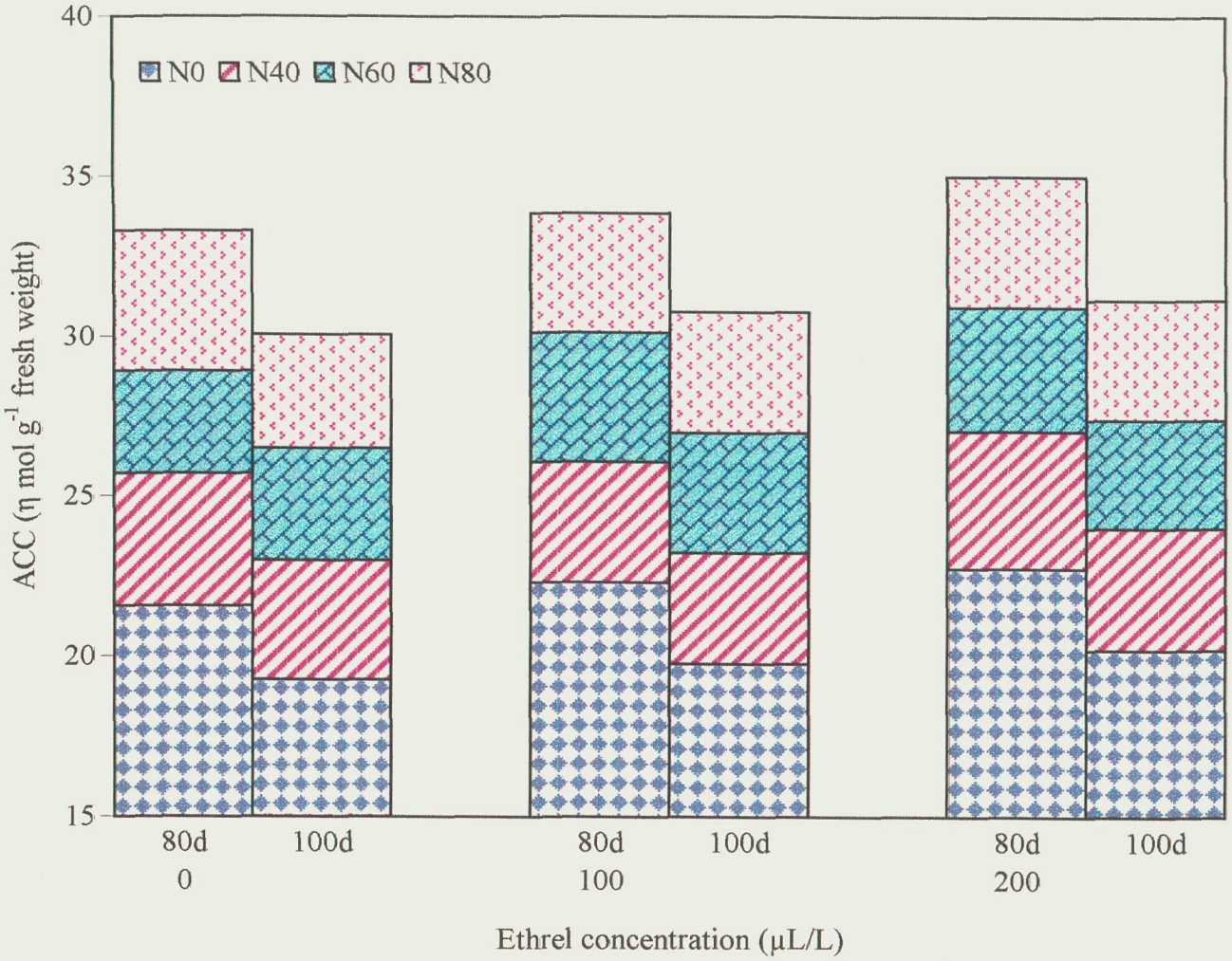


Fig. 11. Effect of ethrel spray on 1-aminocyclopropane-1-carboxylic acid (ACC) of cultivar Alankar of mustard (*Brassica juncea* L.) grown with different levels of nitrogen

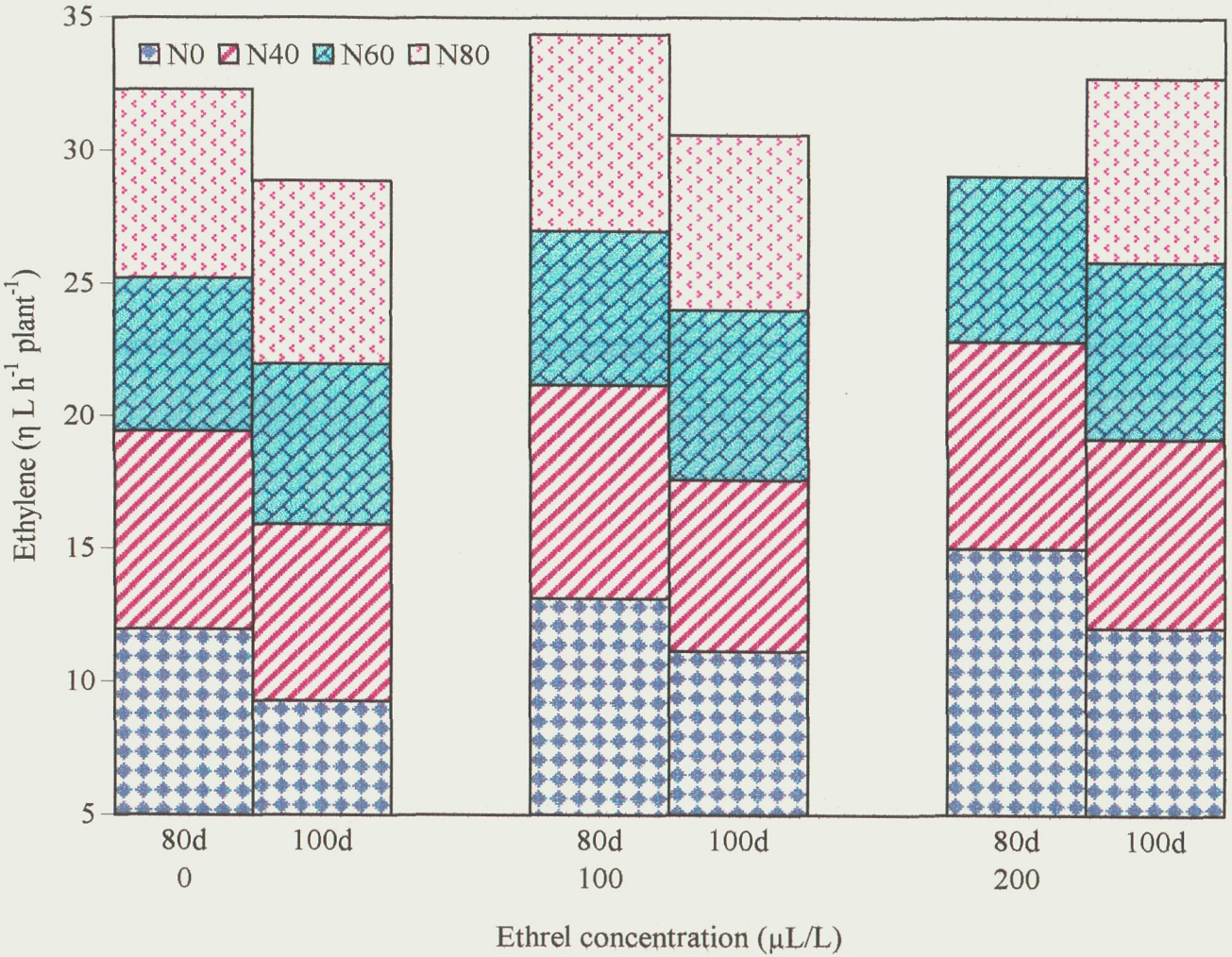


Fig. 13. Effect of ethrel spray on ethylene evolution of cultivar Alankar of mustard (*Brassica juncea* L.) grown with different levels of nitrogen

urea fertilization (Barker and Cory, 1990). Thus, the suitable N availability led to tissue ammonia accumulation and increased ethylene evolution, which triggered many physiological effects and enhanced growth of plants. The obtained dry mass increase in plant (Fig. 10) and its higher distribution in leaf than in stem and pod were because of better management of available photosynthates and source-sink relation. These results were observed in the form of per cent leaf, stem and pod dry weights (Tables 81, 114, 82, 115, 83, 116), specific leaf weight (Tables 76, 109) and enhanced leaf area (Tables 73, 106).

The contribution of leaf dry mass to total dry mass was found to be relatively higher for nitrogen dose 80kg N/ha and sprayed with 200µL/L ethrel than any other treatments. As the growth progressed pod dry mass increased. This was due to remobilization of dry matter from source (leaves) to sink (pods) under the influence of balanced nutrient regime. The balanced nutrient profile helped in maintaining maximum growth characteristics. Together with this, spraying of ethrel also helped the plant to produce signals for better utilization of nutrients (Graan and Boyer, 1990; Zhang and Davies, 1990; Davies and Zhang, 1991; Nilsen and Orcutt, 1996).

The altered structure of canopies in relation to leaf size and leaf area index were helpful in improving solar energy harvesting ability of the leaves as evident from increased plant dry matter production (Tables 77, 110; Fig. 10). Earlier reports from the author's laboratory have shown that spray of 200µL/L of ethrel on mustard plants enhanced dry matter through increase in leaf area index (Khan, 1998; Khan *et al.*, 2000) of mustard grown under non-irrigated conditions. These studies were, however, limited to the use of only a single ethrel concentration and few plant characteristics were studied.

5.3.2 Physiological characteristics

A variety of plant physiological processes at the biochemical and whole plant level are the driving force behind biomass production. Canopy

photosynthesis, integrated over a whole growing season, and whole plant pattern of photoassimilates partitioning is more important physiological determinant of biomass production and crop yield. Rate of photosynthesis is responsive to number of factors, like canopy structure, interception of solar radiation, stomatal conductance, carbon dioxide concentration and levels of ethylene. The degree to which photosynthesis responds to exogenous levels of ethylene is not well understood.

Rates of photosynthesis were increased by 23.7, 27.2, 27.7 and 31.3% with 200µL/L ethrel over control in Experiments 1, 2, 3 and 4 respectively. This ethrel concentration has shown to increase leaf area and leaf area index (discussed in Growth characteristics section). Further, ethrel induced leaf area showed a strong correlation with ethrel-induced photosynthesis (Fig. 21A). Ethrel-induced photosynthesis exhibited strong relationship with ethrel-induced carboxylation efficiency (Fig. 21B). Observations of Buehler *et al.* (1978); Grewal and Kolar (1990) and Grewal *et al.* (1993) have shown the increase in photosynthesis with ethrel due to increase in chlorophyll per unit of leaf area. The increase in photosynthesis with ethrel has also been reported by Subrahmanyam and Rathore (1992a), Pua and Chi (1993) and Khan *et al.* (2000). Retaining higher leaf area index in ethrel-treated plants helped in an increase in photosynthesis. However, at 100d, inspite of increase in leaf area, the photosynthesis rate declined because of mutual shading of leaves. Ethrel concentrations higher than 200µL/L in Experiments 1 and 2 decreased the photosynthesis. Inhibition of photosynthesis in these experiments was because of higher amount of ethylene evolution due to 400–600µL/L ethrel application. Such conditions of inhibition of photosynthesis by ethylene have also been suggested by Kays and Pallas Jr (1980) and Rajala and Peltonen-Sainio (2001). This is possible that threshold value for ethylene with 200µL/L ethrel was comparable to that which elicits the ethylene induced hormonal responses.

In the reported observation, a correlation between ethrel-induced photosynthesis and stomatal conductance (Fig. 22B) suggests that differences in stomatal conductance contributed significantly to the variation in photosynthesis. Analysis of A/Ci values (carboxylation efficiency) also suggests non-stomatal limitation to photosynthesis. The correlation studies showed that variation in photosynthetic capacity (carboxylation efficiency) accounted for the differences in photosynthetic rate (Fig. 21B) more so than differences in stomatal limitation. This view is again strengthened by the observed relationship of carboxylation efficiency with photosynthetic water use efficiency (Fig. 22A). Vanden Boogard *et al.* (1995) reported a correlation between photosynthetic water use efficiency with rubisco activity and photosynthetic water use efficiency as a measure of rubisco activity. Water use efficiency measured from the data on biomass and transpiration rate showed that it was increased maximally with 200µL/L ethrel. The effect of ethrel on water use efficiency was through maintenance of turgor potential and stomatal movement. At maturity, high water use efficiency was caused by lower transpiration rate associated with a high leaf area per unit plant weight, also observed by Vanden Boogard (1996a, b). Similarly, nutrients have also been shown to have a role in water use efficiency of plants (Payne *et al.*, 1992; Bruck *et al.*, 2000). Ethylene-enhanced net photosynthetic rate helped in an increase in plant dry weight, therefore photosynthetic water use efficiency showed relationship with plant dry weight (Fig. 23A–B).

Contrasting reports on exogenously applied ethylene sources on transpiration rate appear in the literature. Transpiration is reportedly non responsive to ethylene in both herbaceous and woody species (Aharnoi, 1978; Pallaghy and Raichke, 1972; Johnson, 1984). In contrast, significant responses in transpiration are shown in several herbaceous species (Govindarajan and Pooviah, 1982; Kays and Pallas Jr, 1980; Pallas Jr and Kays, 1982). Increase in carboxylation efficiency and photosynthesis was related to the increase in

intercellular carbon dioxide concentration by ethrel. At later maturity stages decrease in photosynthesis was related to resistance to CO_2 diffusion and was stomatal limitation. Moreover, Mattoo and White (1991) reported that CO_2 could promote or inhibit ethylene evolution, depending on the tissue concentration. On the same lines Dharan *et al.* (1981), Kao and Yang (1982) and Grodzinski *et al.* (1982) reasoned that inhibition of ethylene evolution resulted from a decrease in internal CO_2 concentration and regulated photosynthesis. In this study, 200µL/L ethrel significantly favoured ethylene evolution that fundamentally influenced the central regulatory system. Further, increase in ethrel concentration (400 or 600µL/L) possibly promoted ethylene evolution to inhibit the physiological and biochemical processes. It seems probable that there is some requirement of ethylene for optimum response. Low and high concentrations represent the two ends of an optimum curve, like that for many hormones, promoting at low concentration and inhibiting at high. There is, thus, an interrelation between CO_2 metabolism and ethylene evolution, which controls other biochemical and physiological changes. Ethylene evolution was linked with activity of ACC oxidase. It was possible that stimulatory effect of ethrel on ACC oxidase might involved not only on enhancement of the activity but also its synthesis and degradation, thereby, resulting in higher ACC dependent ethylene evolution. It may be emphasized that ethrel application promoted ACC dependent ethylene evolution (Tables 96, 129).

Mattoo *et al.* (1997) observed that autocatalytic effect of ethylene was physiologically achieved by an enhancement in the activities of both ACC synthase and ACC oxidase. It may be reiterated that the high conversion rate of ACC to ethylene permitted to influence the fundamental control system. The concentration of ethylene with spray of 200µL/L ethrel showed most suitable concentration for plant growth and development. The concentration of ethylene

with 100μL/L ethrel remained below a critical threshold and higher concentration than 200μL/L possibly exceeded threshold values of ethylene.

In Experiment 5, application of 200μL/L ethrel was used to promote ethylene evolution together with 1mM of silver thiosulphate (STS) to block the action of ethylene. The objective was to test the hypothesis that ethylene has a central role in mediating plant responses. reported in Experiment 1–4.

The hypothesis that ethylene was responsible for the observed enhancement in plant characteristics with 200μL/L ethrel was substantiated by this experiment (Experiment 5) where ethrel and STS were supplied.

It was discussed in preceding pages that 200μL/L ethrel increased ethylene evolution to optimum concentration causing maximum increase in growth and physiological characteristics Limiting the action of ethylene with STS reduced the plant characteristics. Thus, a reduction of growth and physiological rates was achieved by blocking the ethylene action (Tables 147–166). As STS-treated plants exhibited values lower than the plants treated with water (control), it is possible that the intrinsic ethylene biosynthesis was affected (Fig. 16–18).

5.3.3 Biochemical characteristics

Nitrogen related characteristics were studied in Experiment 3 and 4. Nitrogen status of a plant in a particular spatial or temporal zone exhibits the nutritional requirement of the crop during that period in that part of plant phase. In different water availability regime, the nutrient availability differed, and plant respond to the changing environment by proliferating the roots, which develop deep into the soil layers in search of nutrients and water. Thus, the amounts of nitrogen that can be transported to the shoots depend on the capacity of the roots to absorb nitrogen from the soil and transport them to the transpirational stream. The concentration of nitrogen in growth media exerts a considerable influence on growth and mineral composition of crop plants (Kurvitis and Kirkby, 1980; Gashew and Mugwira, 1981; Ansari, 1990;

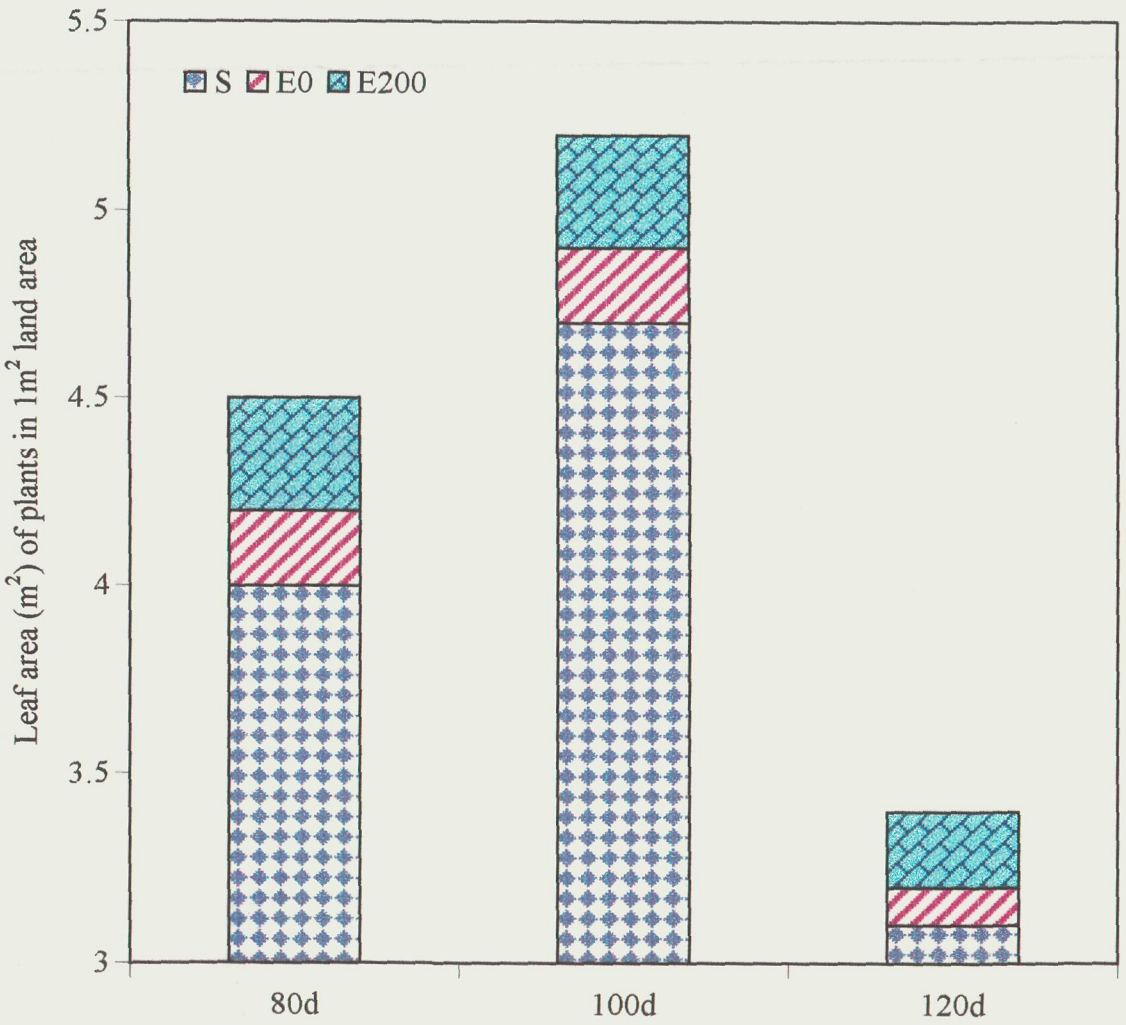


Fig. 16. Effect of ethrel spray (E: 0 or 200 µL/L) or silver thiosulphate (S: 1mM) on leaf area of Alankar cultivar of mustard (*Brassica juncea* L.)

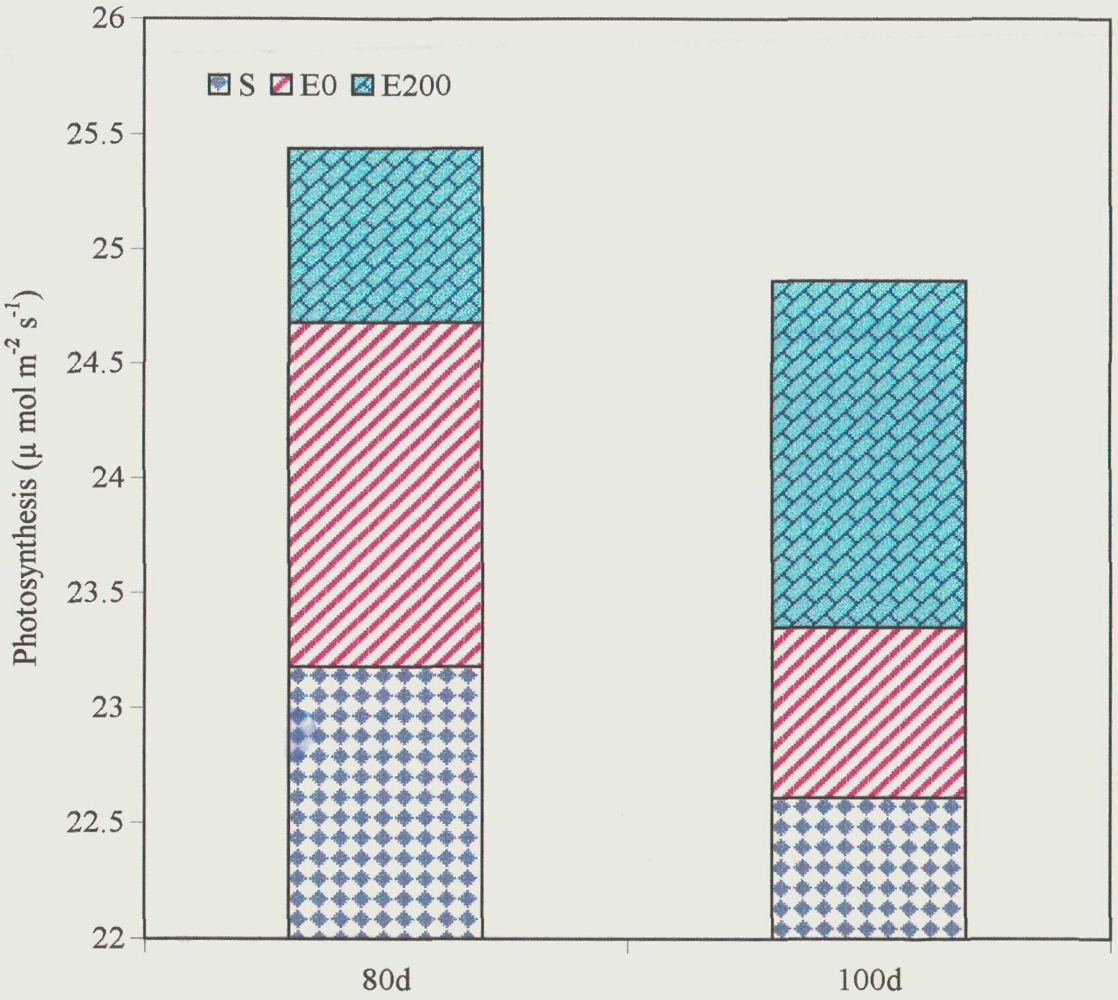


Fig. 17. Effect of ethrel spray (E: 0 or 200 μL/L) or silver thiosulphate (S: 1mM) on net photosynthetic rate of Alankar cultivar of mustard (*Brassica juncea* L.)

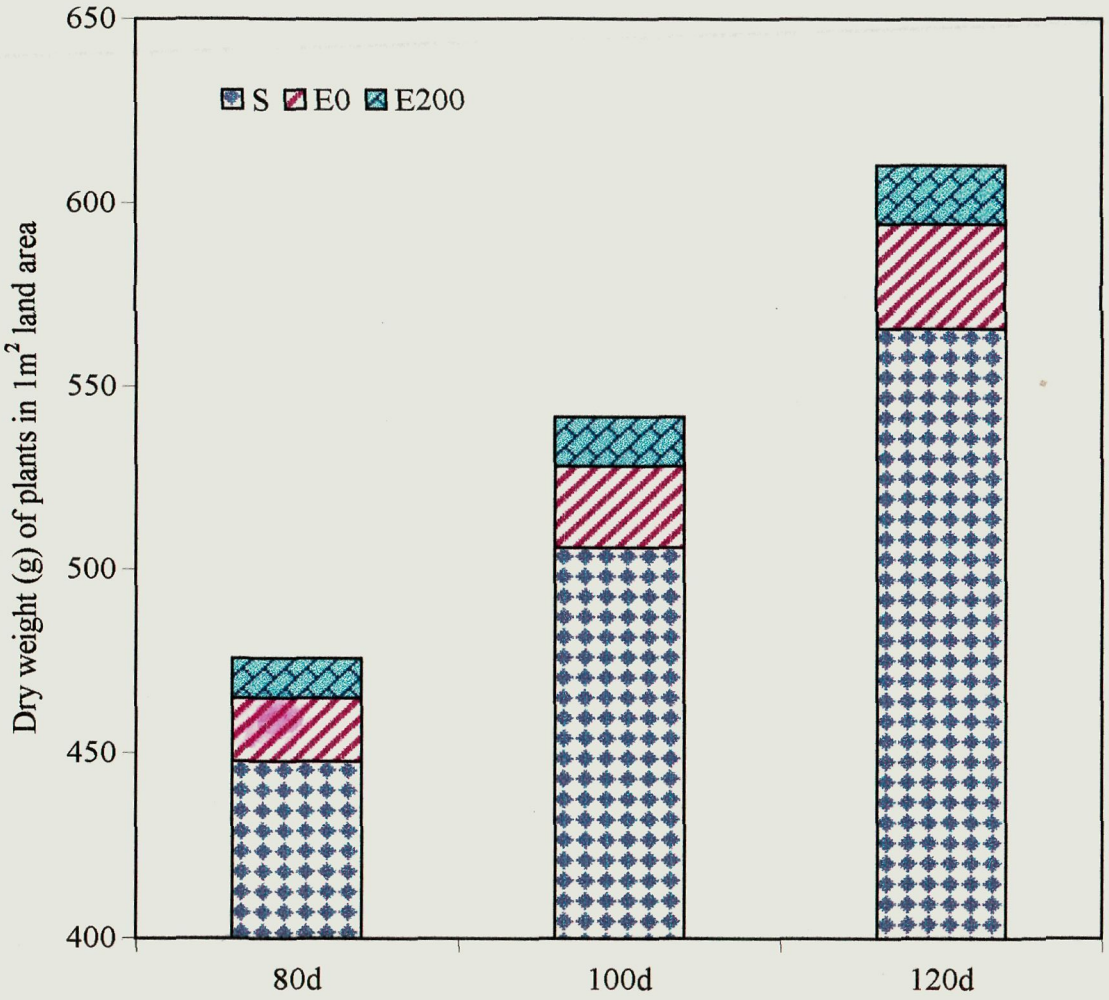


Fig. 18. Effect of ethrel spray (E: 0 or 200 µL/L) or silver thiosulphate (S: 1mM) on dry weight of Alankar cultivar of mustard (*Brassica juncea* L.)

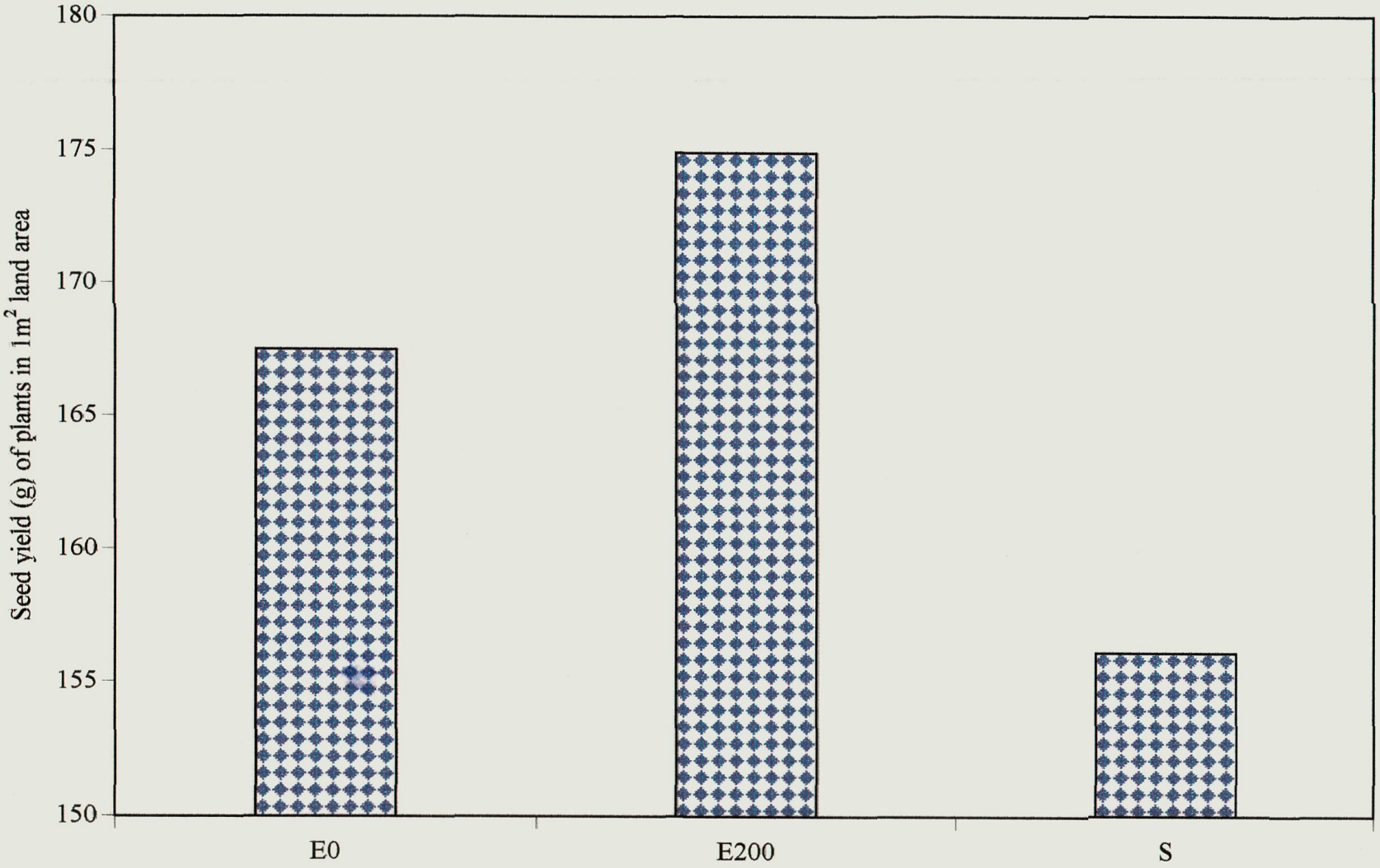


Fig. 19. Effect of ethrel spray (E: 0 or 200 µL/L) or silver thiosulphate (S: 1mM) on seed yield of Alankar cultivar of mustard (*Brassica juncea* L.)

Jeschke *et al.*, 1992) and affects the relation uptake of cations and anions by plants (Kirkby, 1981; Lovatt, 1986).

In the present study, nitrogen content was found to increase with increasing doses of nitrogen. At initial growth stage, nitrogen content increased by 8.6 and 11.5% in Experiment 3 and Experiment 4 respectively with 80kg N/ha applied as compared to 0kg N/ha. The increase in the nitrogen content at early growth stage coincides with the increasing rate of nitrate reductase activity (Tables 97, 130). Nitrogen accumulation was found to be well coordinated with supply of nitrogen. It is believed that availability of a given nutrient may interact with the uptake of other nutrients and thus making the uptake more complex (Amoruwa *et al.*, 1987; Marschner, 1986). The response of accumulation to nitrogen deprivation (0kg N/ha) was negligible for nitrogen content at 80d sampling. The possible explanations are that there was a tendency for the root system to have more proliferation in the soil to meet the plant nutrient demand or it became larger relative to the shoot during nitrogen deprivation. Ethylene regulated differentiation in trachied (Zobel and Roberts, 1978), root elongation (Koning and Jackson, 1979), adventitious root formation (Liu *et al.*, 1990) and root/shoot ratio (Rajala and Peltonen-Sainio, 2001) have been observed. In a study on mustard, Khan *et al.* (1996a) reported increase in nitrate reductase activity with GA_3 application. Enhancement of nitrate reductase activity by GA_3 or GA_3 + cytokinin in tobacco leaves has been observed by Roth-Bejerano and Lips (1970). The accumulation of nitrogen was associated with increased photosynthetic rate, which resulted in higher dry matter accumulation. Together with this other possibility is of accumulation of other cations (preferably potassium), which helped in maintaining the rate of photosynthesis by improving the relative water content of the leaf through osmotic adjustment. In a study on mustard, Khan *et al.* (2000) reported that potassium accumulation increased with nitrogen supply, which caused increase in stomatal conductance, photosynthetic rate and dry matter accumulation.

Regarding this trial, it has been reported that this was a preliminary trial. Accumulation of potassium in guard cells provides the necessary amount of solute for developing the water potential gradient required for water movement into the guard cells for stomatal opening necessary for photosynthesis (Jensen and Tophoj, 1985; Tanguilag *et al.*, 1987 and Thakral *et al.*, 1997). The findings also encourage the view that there is some form of co-regulating of the nutrients accumulation in mustard, which may akin to that described for their accumulation (Vyas *et al.*, 1995; Khan *et al.*, 1997; Zaman and Choudhri, 1998).

5.3.3.1 Nitrogen use efficiency

Nitrogen use efficiency has been defined as seed yield with per unit of available N (soil N + fertilizer N). It has two components, nitrogen uptake efficiency (plant N per unit of soil + fertilizer N) and nitrogen utilization efficiency (seed yield per unit of N in plant). A product of these two components results in nitrogen use efficiency (Moll *et al.*, 1982; Prasad *et al.*, 2000). In the present research, maximal use efficiency of N was found with 200µL/L ethrel and 80kg N/ha (Tables 179–184; Fig. 20). Nitrogen applied in sub-optimal level (40 or 60kg N/ha), the use efficiency was less. At optimal N (80kg N/ha) use efficiency was higher and application of 200µL/L ethrel on plants receiving 80kg N/ha enhanced use efficiency further. It may be mentioned here that treatment 80kg N/ha and 200µL/L ethrel enhanced top growth of plants maximally, which puts demand on soil N to meet the growing need of the shoot. Increased nitrate reductase activity in leaves with 80kg N/ha and ethrel (200µL/L) also supports the incorporation of nitrogen in the shoot. Moreover, plant N was translocated to seed N reflecting more of its translocation on application of ethrel finally increasing the seed yield. Moreover, nitrogen application results in enhanced ethylene evolution, which is reported to increase by excessive ammonia accumulation (Corey *et al.*, 1987; Arshad and Frenkenberger, 1991) and can be induced by urea fertilization

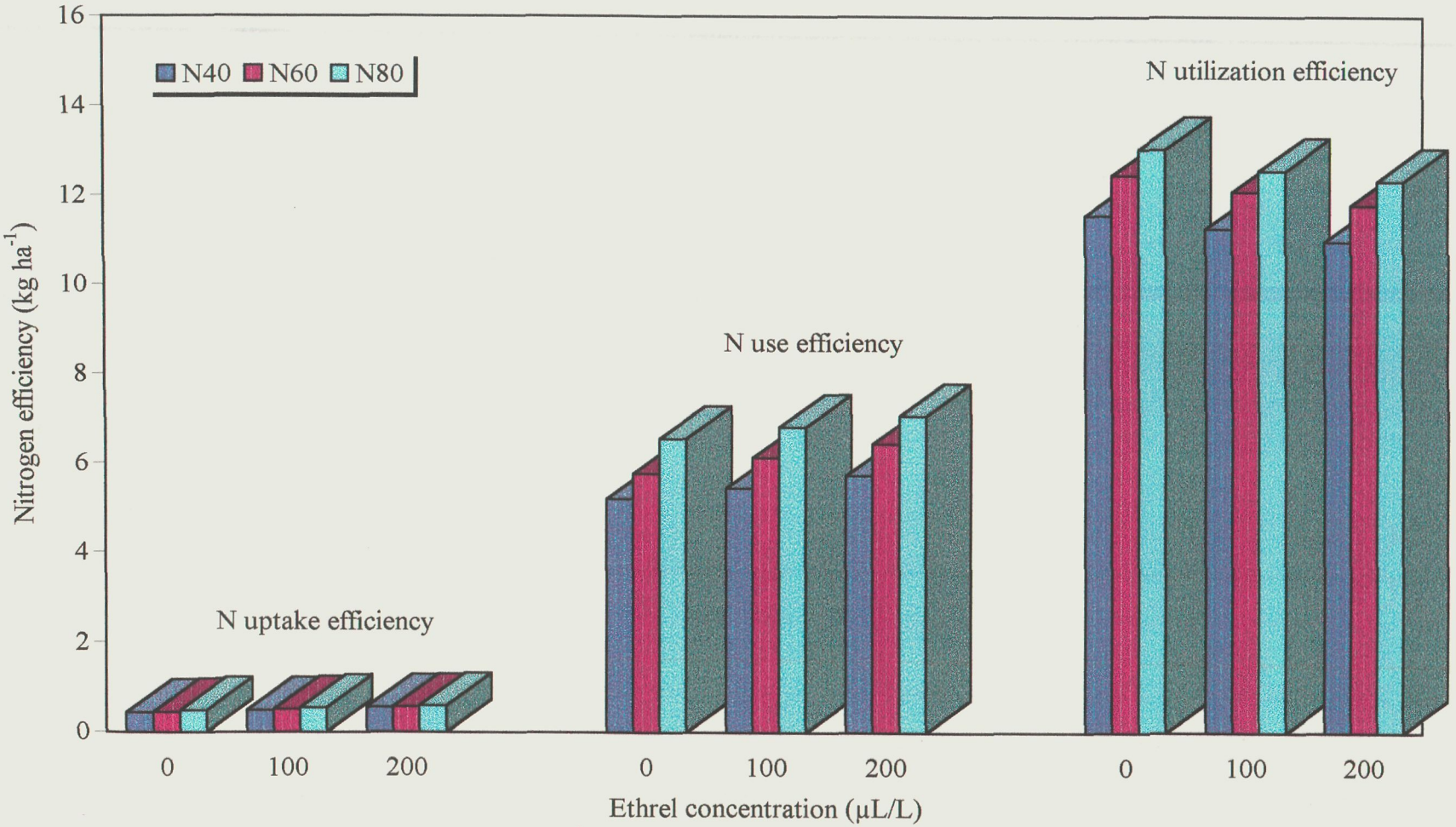


Fig. 20. Effect of ethrel spray on N uptake, N use and N utilization efficiency of cultivar Alankar of mustard (*Brassica juncea* L.) grown with different levels of nitrogen

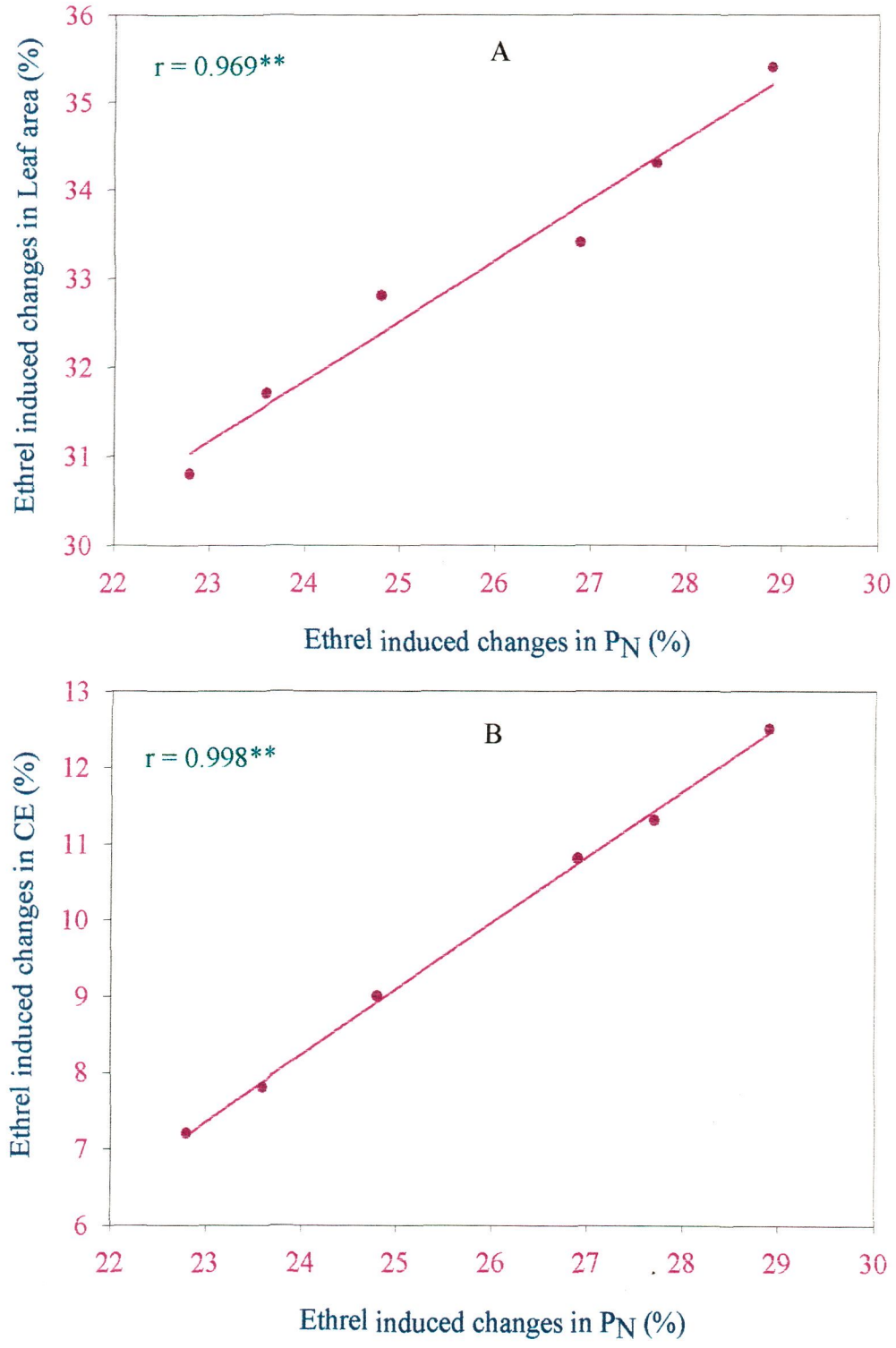


Fig. 21. The relationship between (A) ethrel induced changes in leaf area and ethrel induced changes in net photosynthetic rate (P_N) and (B) ethrel induced changes in carboxylation efficiency (CE) and ethrel induced changes in net photosynthetic rate (P_N). The per cent increase in values from 200 µL/L ethrel over control of the cultivars PBM16 and Alankar in Experiments 1 and 2 were used for these correlation studies. ** significant at P = 0.01.

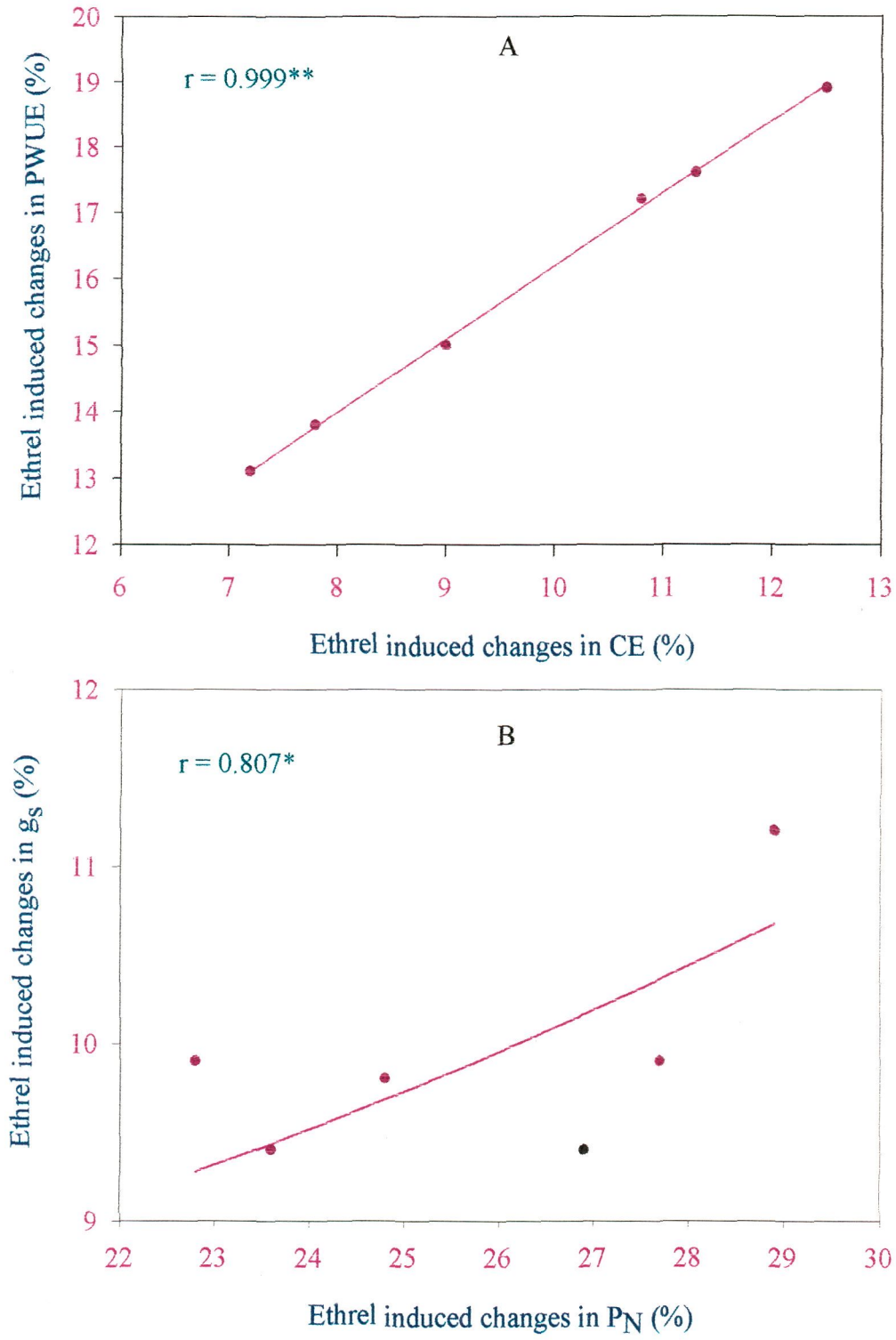


Fig. 22. The relationship between (A) ethrel induced changes in photosynthetic water use efficiency (PWUE) and ethrel induced changes in carboxylation efficiency (CE) and (B) ethrel induced changes in stomatal conductance (g_S) and ethrel induced changes in net photosynthetic rate (P_N). The per cent increase in values from 200 µL/L ethrel over control of the cultivars PBM16 and Alankar in Experiments 1 and 2 were used for these correlation studies. * significant at P = 0.05, ** P = 0.01.

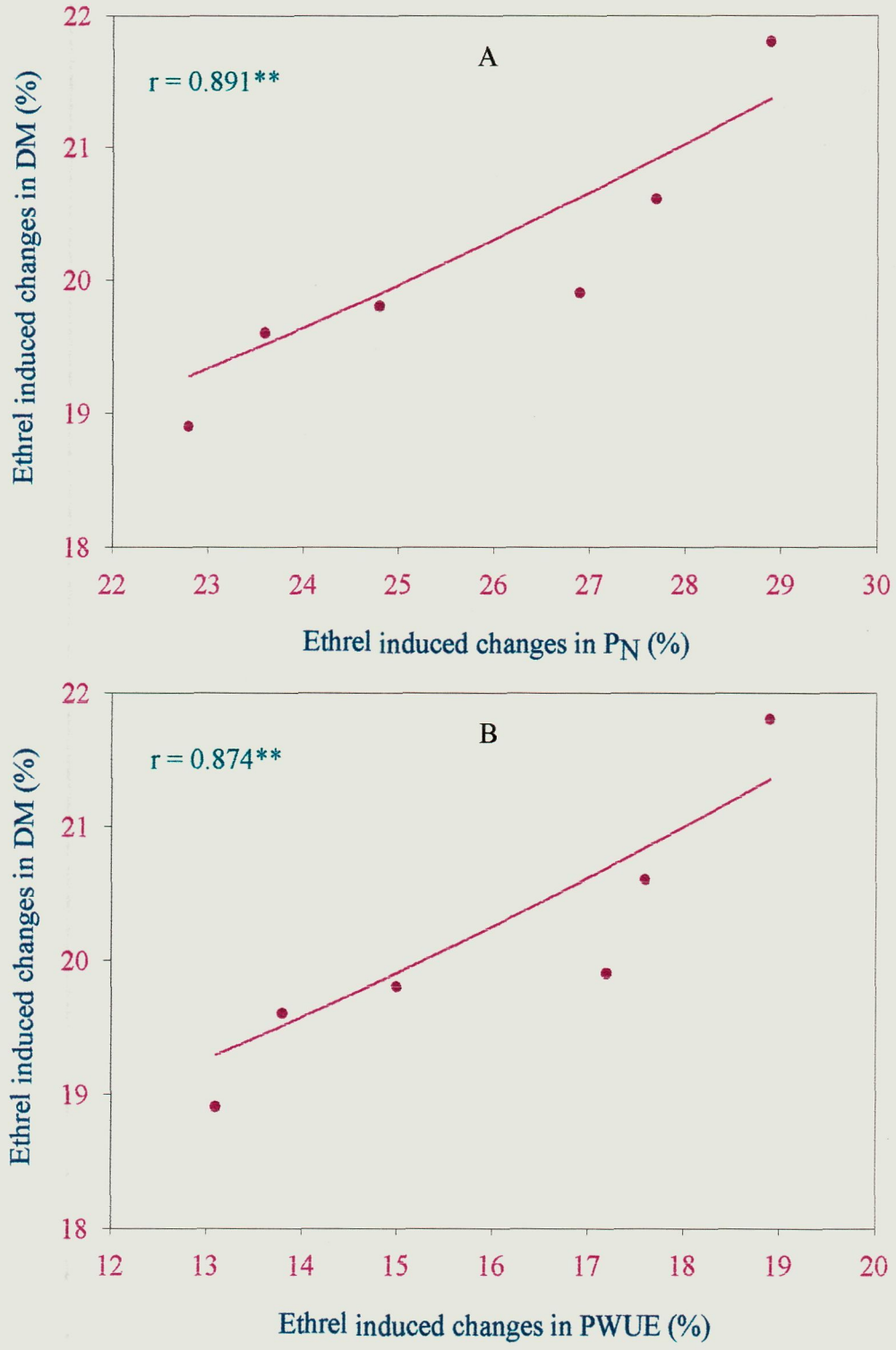


Fig. 23. The relationship between (A) ethrel induced changes in dry mass (DM) and ethrel induced changes in net photosynthetic rate (P_N) and (B) ethrel induced changes in dry mass (DM) and ethrel induced changes in photosynthetic water use efficiency (PWUE). The per cent increase in values from 200 µL/L ethrel over control of the cultivars PBM16 and Alankar in Experiments 1 and 2 were used for these correlation studies. ** significant at P = 0.01.

(Barker and Corey, 1990). Availability of N leads to tissue ammonia accumulation and increased ethylene formation (Feng and Barker, 1992, 1993). Nitrogen use efficiency with fertilizer N has also been reported by Gajri *et al.* (1993), Feiz *et al.* (1994), Gardner *et al.* (1994) and Sowers *et al.* (1994). The effect of GA_3 on the nitrogen use efficiency has been reported from the author's laboratory but the effect of ethrel on nitrogen use efficiency has not been reported earlier

5.3.4 Yield characteristics

Seed yield of a crop may depend on the vegetative growth of the crop because photosynthesizing sites have determinant role in producing the photosynthates. Yield is the final manifestation of several intricate morphological and physiological traits that initiate at germination and terminates at harvest. Yield is dependent on the maintenance of an array of metabolic processes including photosynthesis and hormonal status. There is increasing evidence for metabolic growth regulator effects on various crops.

In fact, leaf size constitutes the canopy structure and is actively involved in interception of solar radiation and in contribution of photoassimilates to the developing pods. Two sequential steps are necessary for a mustard plant to produce pods, a sink of pollinated pods capable of further development must be created and this must be supplied with photosynthates over the subsequent period of development. Thus, seed yield at harvest may be determined either by the seed capacity established at pollination or by the quantity of photosynthate made available between pollination and maturity. There is a positive feed back cycle between photosynthetic products, growth and leaf area. The effectiveness of this cycle is increased under favourable conditions. The CO_2 enrichment through increase in leaf canopy may increase plant growth by stimulating photosynthetic rate and thereby accelerating the cycle (Rogers *et al.*, 1996).

The aim of the Experiments 1 and 2 was find out suitable concentration of ethrel spray on mustard and thereby, if possible to increase seed yield. It was

found that 200μL/L ethrel spray contributed for enhancement of pod number by 11.9 and 14.6 % over control in Experiment 1 and 2 respectively (Tables 31, 59). Primarily, the pod number enhancement contributed to increase of 32.3 and 40.5% seed yield in these experiments. Moreover, increase in number of seeds per pod (14.5% in Experiment 1 and 11.8% in Experiment 2) and slight increase in 1000 seed weight also helped in increasing the seed yield. Increase in seed yield resulted in an increase of 38.8 and 48.3% oil yield in Experiment 1 and Experiment 2 respectively (Tables 32, 60, 33, 61).

In Experiment 3 and 4, it was found that there was differential response of 200μL/L ethrel spray for the yield when the plants were grown with nitrogen deficient (0kg N/ha) to sufficient nitrogen (80kg N/ha). This combination of treatments improved the seed yield by increasing the proportion of the reproductive tissues (inflorescence and/or pods) to total plant dry matter (biological yield). There was 8.9 and 10.5% increase in pod number and 21.0 and 26.4% increase in seed yield in Experiments 3 and 4 respectively (Tables 100, 133, 101, 134). The increase in yield was directly related to the increase in sink capacity. Ethrel application enhanced the incorporation of soil nitrogen (Section 5.3.3), which was manifested in the better vegetative growth (Section 5.3.1) and better partitioning into reproductive parts, evident from increased pod number and harvest index. Linear regression analysis for growth and yield attributing characteristics with seed yield in Experiment 1–4 also confirms the view (Tables 167–178). The beneficial effects of ethrel have also been studied by many research scientists including Dahnous *et al.* (1982), Leary and Oplinger (1983), Wiersma *et al.* (1986), Joshi *et al.* (1987), Singh *et al.* (1987), Ramos *et al.* (1989), Singh and Kumar (1991), Bulman and Smith (1993a, b), Grewal *et al.* (1993) and Kasele *et al.* (1995) in several crop species.

Nitrogen yield potential provides a measure of nitrogen partitioning potential from vegetative parts to seeds. In Experiment 3 and 4, nitrogen yield potential was enhanced by 32.3 and 35.4% respectively due to 200μL/L ethrel

spray (Tables 102, 135). Increase in seed yield has also resulted in increase in oil yield by 30.6 and 36.7% in Experiments 3 and 4 respectively.

5.3.5 Quality characteristics

For assessing oil quality, oil content, acid, iodine and saponification values of oil were determined. It may be added that low acid and iodine values are considered good for oil quality and denote good keeping and easy hydrogenation. High saponification value is good for digestibility and soap making quality.

Ethrel application increased the oil content. The ethrel (ethylene) might have increased the supply carbon to lipid synthesis by induction of a specific transporter and played a role in determining the amount of oil. There is possibility of ethrel (ethylene) affecting acetyl CoA carboxylase. Other workers have also shown that an additional carbon input to lipid synthesis contribute to the oil formation (Post-Beittenmiller *et al.*, 1992; Hunter and Ohlrogge, 1998; Kozaki and Sasaki, 1999; Sawage and Ohlrogge, 1999). Leitch and Kuat (1999) demonstrated role of ethylene applied as ethrel in fatty acid synthesis, increasing the oleic acid in linseed oil. In the present study increase in iodine and saponification values indirectly provide evidence of increase in short chain unsaturated fatty acid. However, the possibility of ethylene affecting acetyl CoA carboxylase and to the flux of carbon to oil in developing embryos of oilseed modifying fatty acid composition needs to be investigated.

Application of nitrogen had not any significant effect in altering oil content of the seed in the present study. However, reports are available for reduced oil content due to N fertilization (Smith *et al.*, 1988; Gendy and Marquard, 1989; Khan *et al.*, 1990; Pinkerton, 1991; Samiullah *et al.*, 1991; Asare and Scarisbrick, 1995). Inspite of non-significant effect on oil content, oil yield was significantly enhanced by ethrel (200µL/L) and 80kg N/ha due to increase in seed yield.

5.4 Conclusion

This has been shown in the study, reported in the thesis, that manipulating the quantity of ethylene alters the leaf expansion and total plant leaf area. Specifically, low concentration of ethylene releasing compound ethrel (200μL/L) stimulated leaf area and higher concentration of ethrel reduced the leaf area. Other effects of ethylene were documented in stomatal and non-stomatal limitations to carboxylation and photosynthesis, which resulted in higher biomass production. In experiments conducted with doses of nitrogen and ethrel, the stimulatory effects of ethylene on nitrate reductase activity and plant nitrogen use efficiency were seen. Enhanced plant top growth due to ethrel (200μL/L) exerted demand on the root for higher utilization of available soil-N.

Nitrogen use efficiency became high and nitrogen accumulation enhanced in the plant above ground part. Nitrogen was incorporated into macromolecules and reflected in higher dry matter accumulation. Efficient partitioning of dry matter resulted in increased seed yield and seed yield potential of the plants.

5.5 Future prospects

The role of plant hormones in growth and development is well known. However, the action of hormones is brought about by producing its effect on other hormones and also controlling the biosynthesis of other hormones. For example, it has been shown that ethylene inhibits GA induced elongation and GA reverses the effects of ethylene. Similarly, the action of ABA inhibits endogenous production of ethylene, but not that formed from ACC and regulates stomatal movements. ABA inhibits the formation of ethylene that is induced by IAA. These aspects of hormonal control over the action of ethylene need to be investigated. It is proposed to work out the level of GA and ABA to have in depth understanding on the regulatory role of ethylene in photosynthesis and biomass accumulation.

CHAPTER–6
SUMMARY

SUMMARY

The thesis "Physiological significance of ethrel (2-chloroethyl phosphonic acid) and nitrogen in relation to growth and metabolism of mustard under irrigated and non-irrigated conditions", contains six chapters.

Chapter 1 deals with the importance of the problem. Lacunae in the understanding of the problem and justifications for undertaking the present study have been put forth.

Chapter 2 is review of literature. Relevant available literature pertaining to individual as well as combined effect of plant growth regulators especially ethylene sources with nitrogen on crop growth and development has been given in this chapter

Chapter 3 describes the details of the material used in the study and methods employed in determining observations carried out in the experiments. Relevant information on meteorological and edaphic data has been included.

In Chapter 4, the results obtained in the experiments which were found significant at $P<0.05$ have been recorded in detail.

In Chapter 5, significant results have been discussed in the light of earlier reported findings. Possible explanations of the data obtained have also been given to reach a conclusion. The results of the five field experiments are summarized below.

Experiment 1 (1998-99) was conducted under irrigated conditions to study the response of two cultivars (Alankar and PBM16) of mustard (*Brassica juncea* L.) to leaf-applied ethrel at 60d after sowing (flowering stage). Alankar is a well established cultivar and accepted by the mustard growers for a decade, whereas PBM16 is a newly released. This was a factorial experiment conducted according to randomized complete block design. The response of the cultivars to ethrel treatments was assessed by determining growth and biochemical characteristics at 80 (pod fill), 100 (pod maturity) and 120d (harvest) after

sowing. Physiological characteristics were studied at 80 and 100d after sowing. Yield and quality characteristics were determined at harvest. Growth characteristics were plant height, plant leaf area, leaf area index, specific leaf area, specific leaf weight, plant dry weight and dry weights and per cent dry weight distribution in leaf, stem and pod, leaf fresh weight, leaf turgid weight and leaf relative water content. Physiological characteristics were, rate of photosynthesis, stomatal conductance, internal CO_2 concentration, transpiration rate, carboxylation efficiency, photosynthetic water use efficiency, plant water use efficiency. Biochemical characteristics included N content and N accumulation in plant. At harvest, yield characteristics studied were, number of pods per plant, number of seeds per pod, 1000 seed weight, seed yield, biological yield, harvest index and oil yield. The oil was assessed for acid, iodine and saponification values.

Among five concentrations of ethrel (0, 100, 200, 400 and 600µL/L) applied, 200µL/L was found superior over others in increasing the plant characteristics studied. The concentration less than 200µL/L was found less effective, whereas concentration higher than 200µL/L proved inhibitory. Spray of 200µL/L ethrel affected growth of the plants and increased total leaf area per plant. Thus, the increase in photosynthesising surface area led to increase in photosynthesis and CO_2 accumulation, which resulted in increased plant dry weight. The other effects of ethrel spray was noted in improved source-sink relationship, as seen in increase in per cent pod dry mass in ethrel-treated plants. More of the flowers developed into pods, evident from higher pod number and seed yield in ethrel-treated plants compared with water-sprayed control. The oil quality was also improved with 200µL/L ethrel spray.

Comparison of the cultivars showed that Alankar established its superiority over PBM16. Growth, physiological, biochemical, yield and quality characteristics were found superior in Alankar than in PBM16. Interaction effect between cultivar and ethrel spray was non-significant for most of the

plant characteristics. This suggests that the two cultivars responded similarly to ethrel spray.

Experiment 2 (1998-99) was a factorial randomized complete block design conducted on the same lines as Experiment 1 but under non-irrigated conditions. The scheme of the treatments, design of the experiment, ethrel spray treatments and cultivars of mustard were also similar as described for Experiment 1. The observations recorded at different sampling stages were similar to Experiment 1. In this experiment, it was noted that ethrel spray at 200μL/L concentration was more effective than any other concentrations used. The effect of the spray was manifested through changes in various characteristics as described for Experiment 1. Alankar cultivar surpassed PBM16 in performance.

Combined analysis of the two experiments showed that the factors irrigated and non-irrigated were non-significant. Ethrel spray under irrigated and non-irrigated conditions was equally effective. The two cultivars also behaved similarly in the two conditions of irrigation.

Experiment 3 (1999-2000) was a factorial randomized complete block design conducted under irrigated conditions to study the effect of leaf-applied 0, 100 and 200μL/L ethrel on the performance of Alankar cultivar of mustard (the cultivar was selected on the basis of Experiment 1) grown with soil-applied 0, 40, 60 and 80kg N/ha. Ethrel spray application was done at 60d after sowing (flowering stage) and performance of the crop was assessed by determining various plant characteristics at 80 (pod fill), 100 (pod maturity) and 120d (harvest) after sowing. Growth characteristics were those studied in Experiment 1. Among physiological characteristics, 1-aminocyclopropane-1-carboxylic acid content, ACC oxidase and ethylene evolution were also studied in addition to the characteristics studied in Experiment 1. Among biochemical characteristics, leaf nitrate reductase activity was also studied in addition to the determination of N content and N accumulation in plant. Among yield

characteristics, seed N, nitrogen harvest index and nitrogen yield potential were also studied in addition to the yield characteristics studied in Experiment 1. Quality characteristics were similar as in Experiment 1.

Ethrel at 200μL/L concentration and nitrogen at 80kg N/ha registered significantly superior values as compared to other treatments. Ethrel (200μL/L) enhanced growth, physiological, biochemical, yield and quality characteristics. In this experiment, it was found that the effect of 200μL/L ethrel was maximal when plants received soil-applied 80kg N/ha. This combination (200μL/L ethrel and 80kg N/ha) enhanced plant leaf area, photosynthesis, CO_2 accumulation and plant dry weight. Water relations characteristics such as leaf fresh weight, leaf turgid weight and leaf relative water content were also enhanced by 200μL/L ethrel x 80kg N/ha. Pod dry weight was maximal with 200μL/L ethrel x 80kg N/ha, which showed higher translocation of dry matter towards sink (pods). Among physiological characteristics, rate of photosynthesis, internal CO_2 concentration, transpiration rate, photosynthetic water use efficiency, water use efficiency, 1-aminocyclopropane-1-carboxylic acid content and ACC oxidase were maximal in 200μL/L ethrel x 80kg N/ha. Plants grown with sufficient soil-applied N (80kg N/ha) responded to the ethrel (200μL/L). However, if soil-applied N was less than 80kg N/ha, the effect of ethrel spray was not prominent. The increased vegetative growth due to ethrel (200μL/L) spray made the plant to extract more of the soil N and was reflected in N content and accumulation and increased growth, physiological, biochemical and yield characteristics. The calculated nitrogen uptake efficiency, nitrogen utilization efficiency and nitrogen-use efficiency showed that nitrogen use was better when plants were treated with the 200μL/L ethrel spray. Seed yield, oil yield and nitrogen yield potential were increased and were maximal with 200μL/L ethrel x 80kg N/ha.

Experiment 4 (1999-2000) was a factorial randomized complete block design conducted simultaneously with the Experiment 3 under non-irrigated

conditions. The scheme of the treatments, ethrel spray concentrations and soil-applied nitrogen were same as in Experiment 3. The data on growth, physiological, biochemical, yield and quality characteristics recorded were those mentioned for Experiment 3. Individual effects of 200µL/L ethrel spray, soil-applied 80kg N/ha and their interaction proved best for most of the plant characteristics. The response of the plant to ethrel and nitrogen treatments was similar as found in Experiment 3.

Combined analysis of Experiments 3 and 4 showed that the response of the plant to ethrel spray, soil-applied nitrogen and their interaction was uniform irrespective of the irrigation conditions. The data on plant characteristics under irrigated and non-irrigated conditions were non-significant. The data suggests that 200µL/L ethrel spray on plants grown with soil-applied 80kg N/ha may be used for improving mustard cultivation irrespective of the conditions of irrigation.

Experiment 5 (2000-2001) was a factorial conducted according to randomized complete block design. In this experiment applications of 0 and 200µL/L ethrel or 1mM silver thiosulphate were done as foliar spray at 60d after sowing (flowering stage) on mustard cultivar Alankar grown under irrigated and non-irrigated conditions. Plants were raised with uniform soil application of 80kg N/ha. This experiment was based on the findings of Experiments 3 and 4. The response of the plants to ethrel spray treatment was confirmed in this experiment with the use of silver thiosulphate spray treatment, as silver thiosulphate application inhibits ethylene action. The observations recorded at 80, 100 and 120d after sowing included growth (plant leaf area plant dry weight), physiological, biochemical, yield and quality characteristics were similar to Experiments 3 and 4. Maximum response was noted with 200µL/L ethrel spray treatment. However, silver thiosulphate spray inhibited the ethylene action and ethrel effect was not observed. The interaction effect of spray and irrigation was found non-significant. The results of the

experiments suggest that response of the plant to ethrel treatment seen in Experiment 1–4 was manifested through the action of ethylene.

The present chapter is followed by bibliography of the literature cited in the thesis Appendix is given in the last to show the preparation of various chemicals used in the study

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APPENDIX

PREPARATION OF REAGENTS

Reagents used in various determinations were prepared as follows:

1. Phosphate buffer (0.1M)

This was prepared by weighing 27.2g of KH_2PO_4 and 45.6g of K_2HPO_4 and dissolving each separately in 1 litre double distilled water. A 16ml of the KH_2PO_4 solution and 84ml of the $K_2H\ PO_4$ solution were then mixed and diluted to 200ml with double distilled water.

2. KNO_3 solution (0.2M)

This was made by weighing 20.2g of potassium nitrate in 1 litre of double distilled water.

3. Isproponol solution (5%)

5ml of isproponol was added to distilled water to make 100ml of solution.

4. Chloramphenical solution (0.5%)

0.5g of chloroamphenical was dissolved to get 100ml with double distilled water.

5. Sulphanilamide in 3NHCl (1%)

1g sulphanilamide was dissolved in 10ml 3NHCl.

6. N-1-Napthyl-ethylene diamine dihydrochloride (NED-HCl) solution (0.2%)

0.2g of N-1-Napthyl-ethylene diamine dihydrochloride was dissolved in double distilled water for the final volume of 100ml.

7. Sodium hydroxide (2.5N NaOH)

This was prepared by dissolving 10.0g of NaOH in double distilled water and the final volume was made 100ml.

8. Nessler's reagent

3.5g of potassium iodide was dissolved in 100ml of double distilled water to which 4 per cent mercuric chloride solution was added with stirring until a slight red precipitate remained. Thereafter, 120g of sodium hydroxide with 250ml of double distilled water were added. The volume was made to one litre. The mixture was decanted and kept in an amber-coloured bottle.

9. Hydrochloride acid (0.5N)

Hydrochloride acid (21.49ml) was mixed with 478.51ml of double distilled water to get 500ml.

10. Iodine monochloride solution

Iodine (13g) was dissolved in a mixture of 300ml of carbontetrachloride and 700ml of glacial acetic acid and the resulting solution was divided in solution A and B. To 20ml of solution A, 15ml of potassium iodide solution and 100ml of double distilled water was added and titrated against 0.1N sodium thiosulphate solution using starch solution as an indicator. Chlorine gas was passed through solution B until the amount of 0.1N sodium thiosulphate solution required for the titration was not more than double of that needed in solution A.

11. Phenolphthalein solution

Phenolphthalein (10g) was dissolved in 95 percent ethanol and the volume was made to 1 litre.

12. Potassium hydroxide (0.1N KOH)

5.6g of KOH was dissolved in 95 per cent ethanol and the volume was made to 1 litre.

13. Potassium hydroxide solution (0.5N)

Potassium hydroxide (28g) was dissolved in 95 per cent ethanol and the volume was made to 1 litre.

14. Potassium iodide solution

Potassium iodide (150g) was dissolved in double distilled water and the volume was made to 1 litre.

15. Sodium thiosulphate solution (0.1N)

Sodium thiosulphate (24.8g) was dissolved in double distilled water and the volume was made to 1 litre.

16. Solvent mixture

Ethanol 95 percent was mixed in diethyl ether in 1:1 ratio. This mixture of solvent was neutralized just before use of 0.1N KOH solution in the presence of phenolphthalein solution as an indicator.

17. Starch solution

Soluble starch (1g) was dissolved in 100ml of boiling double distilled water.

18. Silver thiosulphate solution (1mM)

540mg of $AgNO_3$ was dissolved in 1 litre of double distilled water to get 2.0mM $AgNO_3$ and 1264mg of $Na_2S_2O_3$ was dissolved in 1 litre of double distilled water to get 8mM $Na_2S_2O_3$. The above two solutions were mixed together, resulted in 1mM of silver thiosulphate.

TABLES

Table 7 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant height (cm plant^{-1}) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	90 17	94 43	103 80	101 37	98 03	97 56	94 70	100 63	109 27	106 30	104 20	103 02
PBM16	86 30	90 57	99 00	95 70	93 67	93 05	91 37	95 90	105 77	102 20	99 33	98 91
Mean	88 23	92 50	101 40	98 53	95 85		93 03	98 27	107 52	104 25	101 77	

	120					
Alankar	101 43	106 70	114 90	112 50	110 43	109 19
PBM16	97 30	100 77	111 60	109 50	106 40	105 11
Mean	99 37	103 73	113 25	111 00	108 42	

	L S D at 5%		
	80	100	120
Spray	1 65	1 28	1 28
Cultivar	1 05	0 81	0 81
Interaction	NS	NS	NS

Table 8. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area (cm^2 $plant^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	3077.33	3225.67	3907.00	3584.67	3458.67	3450.67	3295.33	3470.33	4242.00	3993.67	3866.67	3773.60
PBM16	2900.00	3108.00	3684.67	3444.33	3346.00	3296.60	3171.67	3321.00	4096.67	3845.33	3731.00	3633.13
Mean	2988.67	3166.83	3795.83	3514.50	3402.33		3233.50	3395.67	4169.33	3919.50	3798.83	

	120					
Alankar	1880.67	1990.33	2546.00	2394.67	2303.67	2223.07
PBM16	1799.67	1884.00	2453.67	2292.00	2232.33	2132.33
Mean	1840.17	1937.17	2499.83	2343.33	2268.00	

L.S.D. at 5%			
	80	100	120
Spray	30.40	32.61	15.72
Cultivar	19.23	20.63	9.94
Interaction	42.99	NS	NS

Table 9 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area index of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	3 85	4 03	4 88	4 48	4 32	4 31	4 12	4 34	5 30	4 99	4 83	4 72
PBM16	3 63	3 89	4 61	4 31	4 18	4 12	3 96	4 15	5 12	4 77	4 66	4 53
Mean	3 74	3 96	4 74	4 39	4 25		4 04	4 24	5 21	4 88	4 75	

	120					
Alankar	2 35	2 49	3 18	2 99	2 88	2 78
PBM16	2 25	2 36	3 07	2 87	2 79	2 67
Mean	2 30	2 42	3 12	2 93	2 84	

	L S D at 5%		
	80	100	120
Spray	0 04	0 05	0 02
Cultivar	0 02	0 03	0 01
Interaction	0 05	NS	NS

Table 10 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf area (cm^2g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	288.00	291.67	303.67	299.67	295.00	295.60	399.33	406.00	422.33	415.33	410.00	410.60
PBM16	284.33	287.33	300.67	295.33	291.33	291.80	395.67	399.33	416.67	411.00	405.33	405.60
Mean	286.17	289.50	302.17	297.50	293.17		397.50	402.67	419.50	413.17	407.67	

	120					
Alankar	428.67	433.00	447.33	441.33	436.00	437.27
PBM16	425.00	428.33	441.67	436.33	432.00	432.67
Mean	426.83	430.67	444.50	438 83	434.00	

	L.S.D. at 5%		
	80	100	120
Spray	0.99	1.17	1.07
Cultivar	0.62	0.74	0.67
Interaction	NS	NS	NS

Table 11. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf weight (mg cm^{-2}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	3.47	3.42	3.29	3.33	3.38	3.38	2.50	2.46	2.37	2.41	2.44	2.43
PBM16	3.52	3.47	3.32	3.38	3.43	3.42	2.52	2.50	2.40	2.43	2.47	2.46
Mean	3.49	3.45	3.31	3.36	3.41		2.51	2.48	2.38	2.42	2.45	

	120					
Alankar	2.34	2.31	2.23	2.26	2.29	2.29
PBM16	2.35	2.33	2.26	2.29	2.31	2.31
Mean	2.34	2.32	2.25	2.28	2.30	

	L.S.D. at 5%		
	80	100	120
Spray	0.012	0.010	0.010
Cultivar	0.007	0.006	0.006
Interaction	NS	NS	NS

Table 12. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	32.51	33.48	37.78	35.35	34.78	34.78	34.78	35.78	40.01	38.51	37.91	37.40
PBM16	31.17	32.80	36.18	34.58	34.24	33.79	34.02	35.01	39.33	37.67	37.38	36.68
Mean	31.84	33.14	36.98	34.97	34.51		34.40	35.40	39.67	38.09	37.65	37.40

	120					
Alankar	36.99	38.05	43.11	41.61	40.99	40.15
PBM16	36.21	37.15	42.46	40.77	40.49	39.42
Mean	36.60	37.60	42.79	41.19	40.74	

	L.S.D. at 5%		
	80	100	120
Spray	0.31	0.32	0.32
Cultivar	0.20	0.20	0.20
Interaction	0.44	NS	NS

Table 13 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (g plant^{-1}) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	10.68	11.05	12.87	11 95	11.71	11 65	8 25	8 54	10 04	9.61	9.43	9 17
PBM16	10.19	10.78	12 25	11 65	11 48	11 27	8 01	8 31	9 83	9.35	9 20	8 94
Mean	10.44	10.92	12 56	11 80	11 60		8 13	8 43	9 94	9.48	9.31	

	120					
Alankar	4.39	4.59	5 69	5.42	5.28	5 07
PBM16	4.23	4.40	5 55	5.25	5 17	4.92
Mean	4.31	4.50	5.62	5 34	5.22	

L.S.D at 5%			
	80	100	120
Spray	0.10	0.08	0.04
Cultivar	0.06	0.05	0.02
Interaction	0.14	NS	NS

Table 14 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (g plant $^{-1}$) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	19 10	19 48	21 07	19 87	19 63	19 83	20 78	21 20	22 74	22 08	21 80	21 72
PBM16	18 39	19 18	20 27	19 54	19 44	19 36	20 46	20 88	22 42	21 72	22 05	21 51
Mean	18 75	19 33	20 67	19 70	19 54		20 62	21 04	22 58	21 90	21 93	

	120					
Alankar	23 79	24 34	26 63	25 90	25 65	25 26
PBM16	23 39	23 90	26 33	25 50	25 43	24 91
Mean	23 59	24 12	26 48	25 70	25 54	

	L S D at 5%		
	80	100	120
Spray	0 20	0 19	0 23
Cultivar	0 12	0 12	0 14
Interaction	0 28	0 27	NS

Table 15. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.73	2.94	3.85	3.53	3.43	3.30	5.75	6.04	7.23	6.83	6.68	6.50
PBM16	2.58	2.84	3.66	3.40	3.32	3.16	5.55	5.82	7.08	6.60	6.14	6.24
Mean	2.66	2.89	3.75	3.47	3.38		5.65	5.93	7.16	6.71	6.41	

	120					
Alankar	8.81	9.12	10.79	10.29	10.06	9.81
PBM16	8.59	8.85	10.58	10.02	9.89	9.59
Mean	8.70	8.98	10.69	10.16	9.98	

	L.S.D. at 5%		
	80	100	120
Spray	0.03	0.06	0.06
Cultivar	0.02	0.04	0.04
Interaction	NS	0.09	NS

Table 16. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	32.85	33.02	34.05	33.81	33.68	33.48	23.71	23.88	25.10	24.95	24.86	24.50
PBM16	32.70	32.87	33.85	33.68	33.52	33.32	23.54	23.73	24.99	24.82	24.68	24.35
Mean	32.77	32.94	33.95	33.74	33.60		23.63	23.81	25.05	24.89	24.77	

	120					
Alankar	11.86	12.07	13.20	13.03	12.90	12.61
PBM16	11.68	11.84	13.08	12.87	12.76	12.44
Mean	11.77	11.96	13.14	12.95	12.83	

	L.S.D. at 5%		
	80	100	120
Spray	0.08	0.07	0.05
Cultivar	0.05	0.04	0.03
Interaction	NS	NS	NS

Table 17 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (%) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	58 75	58 19	55 76	56 19	56 45	57 07	59 75	59 25	56 83	57 32	57 51	58 13
PBM16	59 01	58 47	56 04	56 50	56 77	57 36	60 14	59 64	57 00	57 66	58 97	58 68
Mean	58 88	58 33	55 90	56 35	56 61		59 95	59 45	56 91	57 49	58 24	

	120					
Alankar	64 33	63 96	61 76	62 24	62 57	62 97
PBM16	64.59	64.35	62 00	62 54	62 80	63 26
Mean	64 46	64 15	61 88	62 39	62 69	

	L S D at 5%		
	80	100	120
Spray	0 12	0 10	0.09
Cultivar	0 08	0 07	0 06
Interaction	NS	0 15	NS

Table 18. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	8.40	8.79	10.19	9.99	9.87	9.45	16.53	16.87	18.07	17.72	17.62	17.36
PBM16	8.29	8.66	10.11	9.82	9.70	9.32	16.32	16.62	18.01	17.52	16.41	16.98
Mean	8.34	8.72	10.15	9.91	9.79		16.43	16.75	18.04	17.62	17.02	

	120					
Alankar	23.81	23.97	25.04	24.73	24.54	24.42
PBM16	23.73	23.82	24.92	24.58	24.43	24.29
Mean	23.77	23.89	24.98	24.66	24.49	

	L.S.D. at 5%		
	80	100	120
Spray	0.07	0.06	0.07
Cultivar	0.04	0.04	0.04
Interaction	NS	0.09	NS

Table 19. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf fresh weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	44.86	47.00	55.71	51.32	49.70	49.72	32.22	33.68	40.51	38.54	37.34	36.46
PBM16	42.40	45.06	52.52	49.59	48.62	47.64	30.87	32.33	39.14	37.03	35.98	35.07
Mean	43.63	46.03	54.12	50.45	49.16		31.55	33.00	39.82	37.79	36.66	

	120					
Alankar	16.26	17.17	21.84	20.71	19.87	19.17
PBM16	15.49	16.23	20.95	19.74	19.17	18.31
Mean	15.88	16.70	21.40	20.22	19.52	

	L.S.D. at 5%		
	80	100	120
Spray	0.40	0.32	0.18
Cultivar	0.25	0.20	0.11
Interaction	0.57	NS	NS

Table 20. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf turgid weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	66.22	68.02	76.55	72.32	70.87	70.79	54.09	55.96	63.26	61.51	60.33	59.03
PBM16	63.70	66.84	73.48	71.05	70.01	69.01	53.26	54.85	62.40	60.30	59.34	58.03
Mean	64.96	67.43	75.02	71.68	70.44		53.68	55.40	62.83	60.91	59.83	

	120					
Alankar	30.27	31.35	37.55	36.33	35.37	34.17
PBM16	29.40	30.34	36.93	35.44	34.88	33.40
Mean	29.83	30.84	37.24	35.89	35.13	

	L.S.D. at 5%		
	80	100	120
Spray	0.60	0.65	0.25
Cultivar	0.38	0.41	0.16
Interaction	0.84	NS	NS

Table 21. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf relative water content (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	61.55	63.11	67.27	65.21	64.18	64.26	51.91	53.01	57.23	55.75	54.83	54.54
PBM16	60.19	61.16	65.71	63.88	63.45	62.88	50.51	51.61	55.76	54.32	53.41	53.12
Mean	60.87	62.13	66.49	64.54	63.82		51.21	52.31	56.50	55.03	54.12	

	120					
Alankar	45.89	47.00	50.68	49.45	48.47	48.30
PBM16	44.73	45.60	49.08	47.99	47.12	46.91
Mean	45.31	46.30	49.88	48.72	47.80	

	L.S.D. at 5%		
	80	100	120
Spray	0.25	0.23	0.30
Cultivar	0.16	0.15	0.19
Interaction	0.35	NS	NS

Table 22. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on rate of photosynthesis (μ mol $m^{-2}s^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (μL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	17.15	18.33	21.16	20.12	19.24	19.20	15.08	16.30	19.36	18.12	17.24	17.22
PBM16	16.22	17.28	20.14	19.14	18.25	18.21	14.35	15.27	18.50	17.30	16.36	16.36
Mean	16.69	17.81	20.65	19.63	18.75		14.72	15.78	18.93	17.71	16.80	

	L.S.D. at 5%	
	80	100
Spray	0.19	0.23
Cultivar	0.12	0.14
Interaction	NS	NS

Table 23. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stomatal conductance (mol $m^{-2}s^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	0.44	0.45	0.48	0.46	0.45	0.45	0.41	0.42	0.45	0.44	0.43	0.43
PBM16	0.42	0.44	0.46	0.45	0.44	0.44	0.41	0.42	0.44	0.43	0.42	0.42
Mean	0.43	0.44	0.47	0.46	0.45		0.41	0.42	0.44	0.43	0.42	

	L.S.D. at 5%	
	80	100
Spray	0.006	0.006
Cultivar	0.004	0.004
Interaction	NS	NS

Table 24. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on internal CO_2 concentration (μ mol mol^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (μL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	273.03	283.53	312.13	301.50	292.67	292.57	263.43	272.43	302.20	292.20	281.40	282.33
PBM16	267.03	275.60	301.43	292.77	283.83	284.13	258.07	267.33	294.43	284.80	275 30	275.99
Mean	270.03	279.57	306.78	297.13	288.25		260 75	269.88	298 32	288 50	278 35	

	L.S.D. at 5%	
	80	100
Spray	2.96	3.35
Cultivar	1.87	2.12
Interaction	NS	NS

Table 25. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on transpiration rate (kg m^{-2} day^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	12.79	12.87	13.28	13.20	13.16	13.06	10.44	10.59	11.02	10.75	10.70	10.70
PBM16	12.64	12.85	13.20	12.98	12.97	12.93	10.42	10.49	10.92	10.69	10.66	10.64
Mean	12.71	12.86	13.24	13.09	13.07		10.43	10.54	10.97	10.72	10.68	

	L.S.D. at 5%	
	80	100
Spray	0.04	0.03
Cultivar	0.03	0.02
Interaction	0.06	NS

Table 26 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on carboxylation efficiency (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	6.28	6.44	6.77	6.67	6.57	6.55	5.72	5.98	6.40	6.20	6.12	6.08
PBM16	6.40	6.26	6.68	6.53	6.43	6 46	5.56	5.71	6.28	6.07	5.61	5.84
Mean	6.34	6.35	6.73	6.60	6.50		5.64	5.84	6 34	6.14	5.86	

	L.S D. at 5%	
	80	100
Spray	0.19	0.25
Cultivar	NS	0.16
Interaction	NS	NS

Table 27. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on photosynthetic water use efficiency (μmolmol^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (μL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	39.28	41.05	44.38	43.74	42.44	42.18	36.48	38.49	43.02	41.51	40.09	39.92
PBM16	38.32	39.58	44.10	42.54	41.80	41.26	35.29	36.65	42.37	40.54	39.26	38.82
Mean	38.80	40.31	44.24	43.14	42.12		35.89	37.57	42.70	41.03	39.67	

	L.S.D. at 5%	
	80	100
Spray	0.32	0.48
Cultivar	0.20	0.30
Interaction	0.45	NS

Table 28. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant water use efficiency (mg g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.54	2.60	2.84	2.68	2.64	2.66	3.30	3.38	3.63	3.58	3.54	3.49
PBM16	2.46	2.55	2.74	2.66	2.64	2.61	3.27	3.34	3.60	3.52	3.50	3.44
Mean	2.50	2.58	2.79	2.67	2.64		3.28	3.36	3.62	3.55	3.52	

	L.S.D. at 5%	
	80	100
Spray	0.02	0.02
Cultivar	0.01	0.01
Interaction	0.03	NS

Table 29 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen content (%) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.22	2 32	2.41	2.38	2.37	2.34	1.99	2.16	2.32	2.27	2.24	2.20
PBM16	2.13	2 22	2.37	2.33	2.31	2.27	1 85	2.00	2 23	2 13	2.12	2.06
Mean	2.18	2 27	2.39	2.35	2 34		1 92	2.08	2.28	2 20	2.18	

	120					
Alankar	1 74	1 85	2 06	1.95	1 90	1 90
PBM16	1.64	1 74	1 95	1.82	1 80	1 79
Mean	1 69	1 79	2.01	1.88	1 85	

L S D at 5%			
	80	100	120
Spray	0 02	0.04	0.03
Cultivar	0 01	0 02	0.02
Interaction	0.02	NS	NS

Table 30. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen accumulation (mg plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	722.67	775.33	901.33	841.33	824.33	813.00	691.00	771.33	929.67	874.33	849.00	823.07
PBM16	664.00	727.00	856.33	804.33	791.00	768.53	629.67	700.33	875.33	801.33	791.00	759.53
Mean	693.33	751.17	878.83	822.83	807.67		660.33	735.83	902 50	837.83	820.00	

	120					
Alankar	642.33	702.67	889.67	810.00	777.33	764.40
PBM16	593.67	645.00	826.00	741.67	728.67	707.00
Mean	618.00	673.83	857.83	775.83	753.00	

	L.S.D at 5%		
	80	100	120
Spray	9.08	15.48	12.27
Cultivar	5.75	9.79	7 76
Interaction	NS	NS	NS

Table 31. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight (g) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16

Cultivar	Pods plant^{-1}						Seeds pod^{-1}					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	144.33	148.67	160.33	156.33	153.67	152.67	12.90	13.27	14.77	14.33	14.32	13.92
PBM16	140.33	144.67	158.33	150.67	150.00	148.80	12.75	13.03	14.62	14.20	14.17	13.75
Mean	142.33	146.67	159.33	153.50	151.83		12.83	13.15	14.69	14.27	14.24	

	1000 seed weight					
Alankar	4.44	4.45	4.58	4.54	4.51	4.51
PBM16	4.41	4.44	4.56	4.51	4.51	4.48
Mean	4.43	4.45	4.57	4.53	4.51	

	L.S.D. at 5%		
	Pods plant^{-1}	Seeds pod^{-1}	1000 seed weight
Spray	1.67	0.08	0.01
Cultivar	1.05	0.05	0.01
Interaction	NS	NS	NS

Table 32. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on seed yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16

Cultivar	Sampling stage (days after sowing)											
	Seed yield						Biological yield					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	10.33	10.98	13.55	12.73	12.41	12.00	46.23	47.57	53.89	52.02	51.23	50.19
PBM16	9.87	10.46	13.19	12.05	11.97	11.51	45.27	46.43	53.08	50.97	50.62	49.27
Mean	10.10	10.72	13.37	12.39	12.19		45.75	47.00	53.49	51.49	50.93	

	Harvest index					
Alankar	22.35	23.07	25.15	24.46	24.21	23.85
PBM16	21.80	22.52	24.85	23.64	23.65	23.29
Mean	22.07	22.80	25.00	24.05	23.93	

	L.S.D. at 5%		
	Seed yield	Biological yield	Harvest index
Spray	0.20	0.39	0.28
Cultivar	0.13	0.25	0.17
Interaction	NS	NS	NS

Table 33. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on oil yield (q ha^{-1}) and oil content (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16

Cultivar	Sampling stage (days after sowing)											
	Oil yield						Oil content					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	3.63	3.90	5.02	4.65	4.45	4.33	35.19	35.52	37.07	36.55	35.91	36.05
PBM16	3.43	3.66	4.77	4.32	4.22	4.08	34.72	35.00	36.15	35.85	35.28	35.40
Mean	3.53	3.78	4.90	4.48	4.34		34.96	35.26	36.61	36.20	35.60	

	L.S.D. at 5%	
	Oil yield	Oil content
Spray	0.07	0.09
Cultivar	0.04	0.06
Interaction	NS	0.13

Table 34. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on acid value, iodine value and Saponification value of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16

Cultivar	Sampling stage (days after sowing)											
	Acid value						Iodine value					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	3.26	3.56	3.97	3.84	3.68	3.66	96.40	97.51	99.28	98.62	97.72	97.91
PBM16	3.04	3.21	3.53	3.40	3.29	3.30	95.84	96.33	97.53	97.14	96.79	96.73
Mean	3.15	3.39	3.75	3.62	3.49		96.12	96.92	98.41	97.88	97.25	

	Saponification value					
Alankar	142.80	145.22	147.46	147.02	146.71	145.84
PBM16	140.33	143.59	146.30	145.30	144.37	143.98
Mean	141.57	144.40	146.88	146.16	145.54	

	L.S.D. at 5%		
	Acid value	Iodine value	Saponification value
Spray	0.06	NS	0.53
Cultivar	0.04	NS	0.33
Interaction	0.09	NS	NS

Table 35. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant height (cm plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	64.37	67.27	74.93	71.87	69.60	69.61	69.17	71.97	79.17	76.87	75.13	74.46
PBM16	60.43	62.97	70.13	67.30	64.33	65.03	64.47	67.83	74.40	72.43	69.63	69.75
Mean	62.40	65.12	72.53	69.58	66.97		66.82	69.90	76.78	74.65	72.38	

	120					
Alankar	74.07	77.27	84.27	83.00	80.20	79.76
PBM16	67.97	70.23	79.80	76.33	73.23	73.51
Mean	71.02	73.75	82.03	79.67	76.72	

	L.S.D. at 5%		
	80	100	120
Spray	1.38	1.45	1.20
Cultivar	0.87	0.92	0.76
Interaction	NS	NS	NS

Table 36. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area (cm^2 $plant^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2160.33	2356.67	2950.00	2760.67	2634.33	2572.40	2317.67	2531.33	3244.33	3046.00	2929.00	2813.67
PBM16	2042.33	2234.67	2755.33	2610.00	2512.67	2431.00	2222.33	2414.67	3060.33	2908.33	2816.33	2684.40
Mean	2101.33	2295.67	2852.67	2685.33	2573.50		2270.00	2473.00	3152.33	2977.17	2872.67	

	120					
Alankar	1355.33	1456.33	2001.33	1869.00	1789.33	1694.27
PBM16	1251.00	1394.00	1886.67	1766.00	1701.00	1599.73
Mean	1303.17	1425.17	1944.00	1817.50	1745.17	

L.S.D. at 5%			
	80	100	120
Spray	26.46	26.41	24.35
Cultivar	16.73	16.70	15.40
Interaction	37.41	37.35	NS

Table 37. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area index of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.70	2.95	3.69	3.45	3.29	3.22	2.90	3.16	4.06	3.81	3.41	3.47
PBM16	2.55	2.79	3.44	3.26	3.14	3.04	2.78	3.02	3.83	3.64	3.52	3.36
Mean	2.63	2.87	3.57	3.36	3.22		2.84	3.09	3.94	3.72	3.47	

	120					
Alankar	1.69	1.82	2.50	2.34	2.24	2.12
PBM16	1.56	1.74	2.36	2.21	2.13	2.00
Mean	1.63	1.78	2.43	2.27	2.18	

	L.S.D. at 5%		
	80	100	120
Spray	0.03	0.17	0.03
Cultivar	0.02	0.11	0.02
Interaction	0.05	NS	NS

Table 38. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf area (cm^2g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	257.33	261.33	273.00	268.67	263.67	264.80	361.00	365.00	376.67	372.00	368.00	368.53
PBM16	252.67	257.00	267.67	263.33	259.67	260.07	357.00	361.33	371.67	366.00	363.00	363.80
Mean	255.00	259.17	270.33	266.00	261.67		359.00	363.17	374.17	369.00	365.50	

	120					
Alankar	399.67	406.00	423.67	417.00	412.00	411.67
PBM16	392.00	399.67	416.33	409.33	404.00	404.27
Mean	395.83	402.83	420.00	413.17	408.00	

L.S.D. at 5%			
	80	100	120
Spray	0.73	1.07	1.51
Cultivar	0.46	0.67	0.96
Interaction	NS	NS	NS

Table 39. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf weight (mg cm^{-2}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	3.88	3.82	3.66	3.72	3.79	3.77	2.77	2.74	2.65	2.69	2.71	2.71
PBM16	3.95	3.88	3.73	3.79	3.85	3.84	2.80	2.77	2.69	2.73	2.75	2.74
Mean	3.92	3.85	3.70	3.76	3.82		2.79	2.75	2.67	2.71	2.73	

	120					
Alankar	2.50	2.46	2.36	2.40	2.42	2.43
PBM16	2.55	2.50	2.40	2.44	2.48	2.47
Mean	2.53	2.48	2.38	2.42	2.45	

	L.S.D. at 5%		
	80	100	120
Spray	0.011	0.010	0.010
Cultivar	0.007	0.006	0.007
Interaction	NS	NS	NS

Table 40. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	26.37	28.15	32.46	31.04	30.32	29.67	28.33	30.19	35.63	34.07	33.43	32.31
PBM16	25.46	27.26	31.06	30.04	29.55	28.68	27.53	29.30	34.17	33.16	32.74	31.38
Mean	25.92	27.71	31.76	30.54	29.94		27.88	29.74	34.90	33.62	33.09	

	120					
Alankar	31.09	32.24	38.81	37.20	36.35	35.14
PBM16	29.62	31.77	37.63	36.27	35.83	34.22
Mean	30.36	32.00	38.22	36.74	36.09	

	L.S.D. at 5%		
	80	100	120
Spray	0.29	0.29	0.45
Cultivar	0.19	0.18	0.29
Interaction	NS	NS	NS

Table 41 Effect of ethiel spiay at 60d aftei sowing (DAS, floweiing stage) on leaf diy weight (g plant ^{1}) of mustard (*Brassica juncea* L) cultivar Alankai and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days aftei sowing)											
	80						100					
	Ethrel concentiation (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	8.40	9.01	10.80	10.27	9.99	9 69	6.42	6.93	8 61	8.18	7.96	7.62
PBM16	8 08	8 69	10.28	9 90	9.67	9.32	6.22	6.68	8 23	7.94	7.76	7 37
Mean	8.24	8 85	10 54	10 08	9 83		6 32	6 81	8 42	8 06	7 86	

	120					
Alankar	3 39	3 59	4 72	4 48	4 34	4 10
PBM16	3.19	3 49	4 53	4 31	4.21	3.95
Mean	3 29	3 54	4 63	4 40	4 28	

	L.S.D at 5%		
	80	100	120
Spray	0.09	0.06	0.06
Cultivar	0 05	0.04	0 04
Interaction	NS	0.09	NS

Table 42. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	15.95	16.89	18.47	17.98	17.65	17.39	17.36	18.43	20.80	20.14	19.86	19.32
PBM16	15.47	16.44	17.76	17.48	17.33	16.90	17.01	17.97	20.01	19.65	19.56	18.84
Mean	15.71	16.67	18.12	17.73	17.49		17.19	18.20	20.41	19.90	19.71	

	120					
Alankar	20.54	21.12	25.01	23.76	23.30	22.74
PBM16	19.65	20.90	24.00	23.28	23.08	22.18
Mean	20.10	21.01	24.50	23.52	23.19	

L.S.D. at 5%			
	80	100	120
Spray	0.19	0.19	0.35
Cultivar	0.12	0.12	0.22
Interaction	NS	NS	NS

Table 43 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (μL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.02	2.25	3.19	2.79	2.68	2.59	4.45	4.83	6.21	5.75	5.60	5.37
PBM16	1.91	2.14	3.02	2.66	2.55	2.45	4.30	4.64	5.93	5.56	5.43	5.17
Mean	1.97	2.20	3.11	2.72	2.62		4.37	4.74	6.07	5.66	5.52	

	120					
Alankar	7.16	7.53	9.42	8.96	8.71	8.36
PBM16	6.78	7.38	9.10	8.68	8.54	8.10
Mean	6.97	7.46	9.26	8.82	8.63	

	L.S.D. at 5%		
	80	100	120
Spray	0.03	0.04	0.10
Cultivar	0.02	0.03	0.07
Interaction	NS	0.06	NS

Table 44. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	31.84	32.00	33.28	33.07	32.94	32.63	22.73	22.97	24.17	24.02	23.81	23.54
PBM16	31.72	31.86	33.10	32.95	32.73	32.47	22.60	22.80	24.10	23.95	23.69	23.43
Mean	31.78	31.93	33.19	33.01	32.84		22.67	22.89	24.14	23.99	23.75	

	120					
Alankar	10.90	11.12	12.17	12.04	11.94	11.63
PBM16	10.77	10.98	12.04	11.89	11.75	11.48
Mean	10.84	11.05	12.10	11.97	11.85	

	L.S.D. at 5%		
	80	100	120
Spray	0.23	0.08	0.07
Cultivar	NS	0.05	0.05
Interaction	NS	NS	NS

Table 45. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (μL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	60.50	60.00	56.88	57.93	58.27	58.72	61.51	61.05	58.38	59.10	59.42	59.89
PBM16	60.76	60.29	57.18	58.20	58.65	59.02	61.79	61.35	58.57	59.27	59.72	60.14
Mean	60.63	60.15	57.03	58.07	58.46		61.65	61.20	58.48	59.18	59.57	

	120					
Alankar	66.06	65.51	63.88	63.87	64.09	64.68
PBM16	66.35	65.80	63.77	64.18	64.41	64.90
Mean	66.21	65.66	63.83	64.02	64.25	

L.S.D. at 5%			
	80	100	120
Spray	0.13	0.11	0.25
Cultivar	0.08	0.07	0.16
Interaction	NS	NS	NS

Table 46. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	7.66	7.99	9.84	8.99	8.85	8.66	15.75	15.99	17.44	16.88	16.77	16.57
PBM16	7.51	7.85	9.71	8.84	8.62	8.51	15.60	15.85	17.35	16.78	16.58	16.43
Mean	7.59	7.92	9.77	8.92	8.73		16.68	15.92	17.39	16.83	16.68	

	120					
Alankar	23.03	23.37	24.26	24.08	23.96	23.74
PBM16	22.83	23.22	24.19	23.93	23.83	23.61
Mean	22.96	23.29	24.22	24.01	23.90	

	L.S.D. at 5%		
	80	100	120
Spray	0.07	0.05	0.06
Cultivar	0.04	0.03	0.04
Interaction	NS	NS	NS

Table 47 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf fresh weight (g plant^{-1}) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	29.74	32.36	38 68	36.93	35.65	34 67	20 70	22 67	29.05	27.43	26.27	25.22
PBM16	28.27	30.80	36 69	35 36	33 79	32 98	19 84	21 66	27.44	26 24	25.18	24.07
Mean	29 01	31.58	37 69	36 15	34 72		20 27	22 16	28 24	26 84	25 72	

	120					
Alankar	9.65	10.26	13 70	13.02	12.53	11.83
PBM16	9.02	10.41	13.06	12.39	11.97	11.37
Mean	9.34	10.34	13.38	12.70	12.25	

L S.D at 5%			
	80	100	120
Spray	0.35	0.26	0.35
Cultivar	0.22	0.16	0.22
Interaction	NS	NS	NS

Table 48. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf turgid weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	54.40	58.11	67.52	65.19	63.42	61.73	43.95	47.25	56.85	54.83	53.33	51.24
PBM16	52.90	56.46	64.78	63.34	61.91	59.88	42.94	45.76	54.73	53.62	52.36	49.88
Mean	53.65	57.29	66.15	64.27	62.66		43.45	46.50	55.79	54.22	52.85	

	120					
Alankar	24.24	25.46	32.57	31.36	30.51	28.83
PBM16	22.92	24.93	31.48	30.41	29.68	27.88
Mean	23.58	25.20	32.03	30.88	30.10	

	L.S.D. at 5%		
	80	100	120
Spray	0.57	0.43	0.43
Cultivar	0.36	0.27	0.27
Interaction	NS	NS	NS

Table 49. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf relative water content (%) leaf area index of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	46.43	47.55	49.15	48.58	48.04	47.95	37.79	39.12	42.36	41.26	40.34	40.18
PBM16	45.05	46.29	48.22	47.65	46.17	46.68	37.07	38.32	41.31	40.06	39.06	39.17
Mean	45.74	46.92	48.69	48.11	47.11		37.43	38.72	41.84	40.66	39.70	

	120					
Alankar	30.02	30.49	32.20	31.76	31.25	31.15
PBM16	29.57	30.02	31.65	30.95	30.48	30.53
Mean	29.80	30.25	31.92	31.36	30.88	

	L.S.D. at 5%		
	80	100	120
Spray	0.20	0.18	0.23
Cultivar	0.13	0.12	0.14
Interaction	0.29	0.26	NS

Table 50. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on rate of photosynthesis (μ mol $m^{-2}s^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (μL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	15.49	16.42	19.20	18.40	17.27	17.36	14.42	15.32	18.33	17.13	16.31	16.30
PBM16	14.23	15.37	18.61	17.42	16.34	16.39	13.36	14 44	17.27	16.45	15.21	15.35
Mean	14.86	15.90	18.90	17.91	16.80		13.89	14.88	17.80	16.79	15.76	

	L.S.D. at 5%	
	80	100
Spray	0.36	0.27
Cultivar	0.23	0.17
Interaction	NS	NS

Table 51 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stomatal conductance (mol $m^{-2}s^{-1}$) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	0 41	0 42	0 45	0 44	0 43	0 43	0 40	0 41	0 44	0 43	0 42	0 42
PBM16	0 40	0 41	0 44	0 43	0 42	0 42	0 39	0 40	0 42	0 42	0 40	0 41
Mean	0 41	0 42	0 44	0 43	0 42		0 40	0 41	0 43	0 42	0 41	

	L S D at 5%	
	80	100
Spray	0 007	0 006
Cultivar	0 005	0 004
Interaction	NS	NS

Table 52 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on intake carbon dioxide of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	262 87	272 83	301 53	291 60	283 17	282 40	253 33	262 53	290 97	280 50	271 90	271 85
PBM16	254 00	263 03	294 20	283 17	272 90	273 46	245 13	253 17	283 87	273 93	263 27	263 87
Mean	258 43	267 93	297 87	287 38	278 03		249 23	257 85	287 42	277 22	267 58	

	L S D at 5%	
	80	100
Spray	3 73	3 41
Cultivar	2 36	2 16
Interaction	NS	NS

Table 53. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on transpiration rate (kg m^{-2} day^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	11.40	11.77	12.23	12.13	12.05	11.91	9.28	9.62	10.20	10.09	10.01	9.84
PBM16	11.32	11.68	12.01	11.94	11.90	11.77	9.19	9.46	10.07	10.00	9.95	9.74
Mean	11.36	11.73	12.12	12.03	11.98		9.24	9.54	10.14	10.05	9.98	

	L.S.D at 5%	
	80	100
Spray	0.04	0.05
Cultivar	0.03	0.03
Interaction	0.06	NS

Table 54. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on carboxylation efficiency (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	5.89	6.02	6.36	6.28	6.09	6.13	5.69	5.83	6.30	6.10	5.99	5.98
PBM16	5.60	5.84	6.32	6.15	5.98	5.98	5.45	5.70	6.08	6.00	5.77	5.80
Mean	5.75	5.93	6.34	6.21	6 04		5.57	5.76	6.19	6.05	5.88	

	L.S.D. at 5%	
	80	100
Spray	0.16	0.12
Cultivar	0.10	0.07
Interaction	NS	NS

Table 55. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on photosynthetic water use efficiency ($\mu molmol^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	37.48	38.78	42.99	42.13	39.85	40.24	35.75	37.06	41.98	40.49	38.82	38.82
PBM16	35.27	37.18	42.61	40.51	39.21	38.96	33.96	35.80	40.79	39.48	38.02	37.61
Mean	36.38	37.98	42.80	41.32	39.53		34.86	36.43	41.38	39.99	38.42	

	L.S.D. at 5%	
	80	100
Spray	0.53	0.51
Cultivar	0.33	0.32
Interaction	0.75	NS

Table 56. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant water use efficiency (mg g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80 and 100 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.31	2.39	2.65	2.56	2.51	2.49	3.04	3.14	3.49	3.38	3.34	3.28
PBM16	2.25	2.33	2.59	2.52	2.48	2.43	2.97	3.10	3.39	3.31	3.29	3.21
Mean	2.28	2.36	2.62	2.54	2.50		3.01	3.12	3.44	3.35	3.32	

	L.S.D. at 5%	
	80	100
Spray	0.02	0.02
Cultivar	0.01	0.01
Interaction	NS	NS

Table 57 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen content (%) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2 10	2 18	2 29	2 25	2 24	2 21	1 75	1 94	2 12	2 05	2 03	1 98
PBM16	1 82	1 91	2 20	2 08	2 06	2 01	1 64	1 72	2 10	1 89	1 85	1 84
Mean	1 96	2 05	2 24	2 17	2 15		1 69	1 83	2 11	1 97	1 94	

	120					
Alankar	1 52	1 63	1 79	1 73	1 70	1 67
PBM16	1.44	1 51	1 74	1.69	1 67	1 61
Mean	1 48	1 57	1 77	1.71	1 68	

	L S D at 5%		
	80	100	120
Spray	0.02	0 03	0 02
Cultivar	0 01	0 02	0 01
Interaction	0 03	0 05	0 03

Table 58. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen accumulation (mg plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16 at 80, 100 and 120 DAS

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	553.67	614.67	742.00	698.00	680.00	657.67	493.00	585.33	755.33	697.00	678.33	641.80
PBM16	463.33	519.33	682.33	624.33	609.00	579.67	450.33	502.67	717.33	626.67	605.67	580.53
Mean	508.50	567.00	712.17	661.17	644.50		471.67	544.00	736.33	661.83	642.00	

	120					
Alankar	471.67	524.33	696.00	644.67	616.67	590.67
PBM16	425.33	478.67	654.67	612.67	599.67	554.20
Mean	448.50	501.50	675.33	628.67	608.17	

	L.S.D. at 5%		
	80	100	120
Spray	9.18	14.00	10.75
Cultivar	5.81	8.85	6.80
Interaction	12.99	19.80	NS

Table 59. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight (g) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16

Cultivar	Pods plant^{-1}						Seeds pod^{-1}					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	125.00	129.00	144.00	139.00	136.67	134.73	11.87	11.91	13.28	12.99	12.80	12.57
PBM16	122.00	125.67	139.00	136.00	133.67	131.27	11.80	11.85	13.20	12.83	12.71	12.48
Mean	123.50	127.33	141.50	137.50	135.17		11.84	11.88	13.24	12.91	12.75	

	1000 seed weight					
Alankar	4.11	4.21	4.46	4.37	4.36	4.30
PBM16	3.94	4.14	4.36	4.29	4.28	4.20
Mean	4.03	4.18	4.41	4.33	4.32	

L.S.D. at 5%

	Pods plant^{-1}	Seeds pod^{-1}	1000 seed weight
Spray	1.36	0.05	0.05
Cultivar	0.86	0.03	0.03
Interaction	NS	NS	NS

Table 60. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on seed yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of mustard (*Brassica juncea* L.) cultivar Alankar and PBM16

Cultivar	Sampling stage (days after sowing)											
	Seed yield						Biological yield					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	7.62	8.08	10.67	9.86	9.53	9.15	38.87	40.30	48.52	46.50	45.43	43.92
PBM16	7.10	7.71	10.00	9.36	9.09	8.65	37.03	39.71	47.04	45.34	44.78	42.78
Mean	7.36	7.90	10.34	9.61	9.31		37.95	40.01	47.78	45.92	45.11	

	Harvest index					
Alankar	19.60	20.05	21.99	21.21	20.98	20.77
PBM16	19.16	19.42	21.26	20.61	20.30	20.15
Mean	19.38	19.38	21.63	20.91	20.64	

	L.S.D. at 5%		
	Seed yield	Biological yield	Harvest index
Spray	0.13	0.57	0.17
Cultivar	0.08	0.36	0.11
Interaction	NS	NS	NS

Table 61. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on oil yield (q ha^{-1}) and oil content (%) of mustard (*Brassica juncea* L) cultivar Alankar and PBM16

Cultivar	Sampling stage (days after sowing)											
	Oil yield						Oil content					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.51	2.69	3.67	3.36	3.23	3.09	32.98	33 33	34.42	34.08	33.83	33.73
PBM16	2.26	2.51	3.39	3.12	3.01	2.86	31.81	32 60	33.90	33.35	33.13	32.96
Mean	2.38	2.60	3.53	3.24	3.12		32.40	32.97	34.16	33.72	33.48	

	L.S.D. at 5%	
	Oil yield	Oil content
Spray	0.20	0.15
Cultivar	0.13	0.09
Interaction	NS	0.21

Table 62 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on acid value, iodine value and Saponification value of mustard (*Brassica juncea* L) cultivar Alankar and PBM16

Cultivar	Sampling stage (days after sowing)											
	Acid value						Iodine value					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
Alankar	2.46	2.65	2 98	2.84	2.78	2.74	92.41	93.34	95.17	94.12	93.88	93.79
PBM16	2.16	2.40	2 81	2 67	2 55	2 52	91 72	92 58	94.07	93 65	93 06	93 02
Mean	2.31	2 53	2.89	2 76	2 66		92 06	92 96	94 62	93 89	93 47	

	Saponification value					
Alankar	133.98	136.93	139 41	138 15	137 85	137 26
PBM16	131.68	133.91	136.42	135.15	135.10	134.45
Mean	132.83	135.42	137.91	136.65	136.48	

	L S D at 5%		
	Acid value	Iodine value	Saponification value
Spray	0.06	NS	0.29
Cultivar	0 04	NS	0 19
Interaction	NS	NS	NS

Table 63. Pooled analysis of plant dry weight in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	32.51	33.48	37.78	35.35	34.78	34.78	34.78	35.78	40.01	38.51	37.91	37.40
PBM16	31.17	32.80	36.18	34.58	34.24	33.79	34.02	35.01	39.33	37.67	37.38	36.68
	Non-Irrigated						Non-Irrigated					
Alankar	26.37	28.15	32.46	31.04	30.32	29.67	28.23	30.19	35.63	34.07	33.43	32.31
PBM16	25.46	27.26	31.06	30.04	29.55	28.68	27.53	29.30	34.17	33.16	32.74	31.38
Mean	28.88	30.42	34.37	32.75	32.22		31.14	32.57	37.28	35.86	35.37	

	120					
	Irrigated					
Alankar	36.99	38.05	43.11	41.61	40.99	40.15
PBM16	36.21	37.15	42.46	40.77	40.49	39.42
	Non-Irrigated					
Alankar	31.09	32.24	38.81	37.20	36.35	35.14
PBM16	29.62	31.77	37.63	36.27	35.95	34.25
Mean	33.48	34.80	40.50	38.97	38.44	

	L.S.D. at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Cultivar (B)	0.15	0.18	0.18
A X B	NS	NS	NS
Spray (C)	0.00024	0.00022	0.00059
A X C	NS	NS	NS
B X C	0.0008	NS	NS
A X B X C	NS	NS	NS

Table 64. Pooled analysis of leaf fresh weight in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	44.86	47.00	55.71	51.32	49.70	49.72	32.22	33.68	40.51	38.54	36.34	36.26
PBM16	42.40	45.06	52.52	49.59	48.62	47.64	30.87	32.33	39.14	37.03	35.98	35.07
	Non-Irrigated						Non-Irrigated					
Alankar	29.74	32.36	36.68	36.93	35.65	34.67	20.70	22.67	29.05	27.43	26.27	25.22
PBM16	28.27	30.80	36.69	35.36	33.79	32.98	19.84	21.66	27.44	26.24	25.18	24.07
Mean	36.32	38.81	45.90	43.30	41.94		25.91	27.58	34.03	32.31	30.94	

	120					
	Irrigated					
Alankar	16.26	17.17	21.84	20.71	19.87	19.17
PBM16	15.49	16.23	20.95	19.74	19.17	18.31
	Non-Irrigated					
Alankar	9.65	10.26	13.70	13.02	12.53	11.83
PBM16	9.02	10.41	13.06	12.39	11.97	11.37
Mean	12.61	13.52	17.39	16.46	15.88	

L.S.D. at 5%			
	80	100	120
Irrigation (A)	NS	NS	NS
Cultivar (B)	0.19	0.25	0.22
A X B	NS	NS	NS
Spray (C)	0.0006	0.0027	0.00013
A X C	NS	NS	NS
B X C	0.002	NS	NS
A X B X C	NS	NS	NS

Table 65. Pooled analysis of leaf turgid weight in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	66.22	68.02	76.55	72.32	70.87	70.79	54.43	55.96	63.27	61.51	60.33	59.10
PBM16	63.70	66.84	73.48	71.05	70.01	69.01	53.26	54.85	65.06	60.30	59.34	57.96
	Non-Irrigated						Non-Irrigated					
Alankar	54.40	58.11	67.52	65.19	63.42	61.73	43.95	47.15	56.85	54.83	53.33	51.22
PBM16	52.90	56.46	64.78	63.34	61.91	59.88	42.94	45.76	54.73	53.62	52.36	49.88
Mean	59.31	62.36	70.58	67.97	66.55		48.65	50.93	59.23	57.56	56.34	

	120					
	Irrigated					
Alankar	30.27	31.35	37.55	36.33	35.37	34.17
PBM16	29.40	30.34	36.93	35.44	34.88	33.40
	Non-Irrigated					
Alankar	24.24	25.46	32.59	31.36	30.51	28.83
PBM16	22.92	24.93	31.48	30.74	29.68	27.95
Mean	26.71	28.02	34.64	33.47	32.61	

	L.S.D. at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Cultivar (B)	0.37	0.27	0.26
A X B	NS	NS	NS
Spray (C)	0.003	0.002	0.001
A X C	NS	NS	NS
B X C	0.012	NS	NS
A X B X C	NS	NS	NS

Table 66. Pooled analysis of leaf relative water content in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	61.55	63.11	67.27	65.21	64.18	64.26	51.91	53.01	57.23	55.75	54.83	54.54
PBM16	60.19	61.16	65.71	63.88	63.45	62.88	50.51	51.61	55.76	54.32	53.41	53.12
	Non-Irrigated						Non-Irrigated					
Alankar	46.43	47.55	49.15	48.58	48.05	47.95	37.79	39.12	42.36	41.26	40.34	40.18
PBM16	45.05	46.29	48.22	47.65	46.17	46.68	37.07	38.32	41.31	40.06	39.06	39.17
Mean	53.30	54.53	57.59	56.33	55.46		44.32	45.51	49.17	47.85	46.91	

	120					
	Irrigated					
Alankar	45.89	47.00	50.68	49.45	48.47	48.30
PBM16	44.73	45.60	49.08	47.99	47.12	46.91
	Non-Irrigated					
Alankar	30.02	30.49	32.20	31.76	31.28	31.15
PBM16	29.57	30.02	31.65	30.95	30.48	30.53
Mean	37.55	38.28	40.90	40.04	39.34	

	L.S.D. at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Cultivar (B)	0.15	0.05	0.12
A X B	NS	NS	NS
Spray (C)	NS	NS	NS
A X C	NS	NS	NS
B X C	0.0003	NS	NS
A X B X C	NS	NS	NS

Table 67. Pooled analysis of rate of photosynthesis in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	17.15	18.33	21.16	20.12	19.24	19.20	15.08	16.30	19.36	18.12	17.24	17.22
PBM16	16.22	17.28	20.14	19.14	18.25	18.21	14.35	15.27	18.50	17.30	16.36	16.36
	Non-Irrigated						Non-Irrigated					
Alankar	15.49	16.42	19.20	18.40	17.27	17.36	14.42	15.32	18.33	17.13	16.31	16.30
PBM16	14.23	15.37	18.61	17.42	16.34	16.39	13.36	14.44	17.27	16.45	15.21	15.35
Mean	15.77	16.85	19.78	18.77	17.77		14.30	15.33	18.36	17.25	16.28	

	L.S.D. at 5%	
	80	100
Irrigation (A)	NS	NS
Cultivar (B)	0.10	0.10
A X B	NS	NS
Spray (C)	0.0002	0.0001
A X C	NS	NS
B X C	NS	NS
A X B X C	NS	NS

Table 68. Pooled analysis of carboxylation efficiency in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	6.28	6.44	6.77	6.67	6 57	6.55	5.72	5.98	6.40	6.20	6.12	6.08
PBM16	6.40	6.26	6.68	6.53	6.43	6.46	5.56	5.71	6.28	6.07	5.61	5.84
	Non-Irrigated						Non-Irrigated					
Alankar	5.89	6.02	6.37	6.28	6.09	6.13	5.69	5.83	6.30	6.10	5.99	5.98
PBM16	5.60	5.84	6.32	6.15	5.98	5.98	5.45	5.70	6.08	6.00	5.77	5.80
Mean	6.04	6.14	6.53	6.41	6.27		5.60	5.80	6.26	6.09	5.87	

	L.S.D. at 5%	
	80	100
Irrigation (A)	NS	NS
Cultivar (B)	0.08	0.08
A X B	NS	NS
Spray (C)	NS	NS
A X C	NS	NS
B X C	NS	NS
A X B X C	NS	NS

Table 69. Pooled analysis of photosynthetic water use efficiency in experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	39.28	41.05	44.38	43.74	42.44	42.18	36.48	38.49	43.02	41.51	40.09	39.92
PBM16	38.32	39.58	44.10	42.54	41.80	41.26	35.29	36.65	42.37	40.54	39.26	38.82
	Non-Irrigated						Non-Irrigated					
Alankar	37.48	38.78	42.99	42.13	39.85	40.24	35.75	37.06	41.98	40.49	38.82	38.82
PBM16	35.27	37.18	42.94	40.51	39.21	39.02	33.96	35.80	40.79	39.48	38.02	37.61
Mean	37.59	39.14	43.60	42.23	40.82		35.37	37.00	42.04	40.51	39.05	

	L.S.D. at 5%	
	80	100
Irrigation (A)	NS	NS
Cultivar (B)	0.26	0.06
A X B	NS	NS
Spray (C)	0.001	0.002
A X C	NS	NS
B X C	0.003	NS
A X B X C	NS	NS

Table 70. Pooled analysis of plant water use efficiency in Experiment 1 and 2

Cultivar	Sampling stage (days after sowing)											
	80						100					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	2.54	2.60	2.84	2.68	2.64	2.66	3.30	3.38	3.63	3.58	3.54	3.49
PBM16	2.46	2.55	2.74	2.66	2.64	2.61	3.27	3.34	3.60	3.52	3.50	3.44
	Non-Irrigated						Non-Irrigated					
Alankar	2.31	2.39	2.65	2.49	2.51	2.47	3.04	3.14	3.49	3.38	3.34	3.28
PBM16	2.25	2.33	2.59	2.52	2.48	2.43	2.97	3.10	3.39	3.31	3.29	3.21
Mean	2.39	2.47	2.71	2.59	2.57		3.14	3.24	3.53	3.45	3.42	

	L.S.D. at 5%	
	80	100
Irrigation (A)	NS	NS
Cultivar (B)	0.02	0.01
A X B	NS	NS
Spray (C)	NS	NS
A X C	NS	NS
B X C	NS	NS
A X B X C	NS	NS

Table 71. Pooled analysis of pod number, seed yield and oil yield in Experiment 1 and 2

Cultivar	Pod number						Seed yield					
	Ethrel concentration (µL/L)											
	0	100	200	400	600	Mean	0	100	200	400	600	Mean
	Irrigated						Irrigated					
Alankar	144.33	148.67	160.33	156.33	153.67	152.67	10.33	10.98	13.55	12.73	12.41	12.00
PBM16	140.33	144.67	158.33	150.67	150.00	148.80	9.87	10.46	13.19	12.05	11.97	11.51
	Non-Irrigated						Non-Irrigated					
Alankar	125.00	129.00	144.00	139.00	136.67	134.73	7.62	8.08	10.67	9.86	9.53	9.15
PBM16	122.00	125.67	139.00	136.00	133.67	131.27	7.10	7.71	10.00	9.36	9.09	8.65
Mean	132.92	137.00	150.42	145.50	143.50		8.73	9.31	11.85	11.00	10.75	

	Oil yield					
	Irrigated					
Alankar	3.63	3.90	5.02	4.65	4.45	4.33
PBM16	3.43	3.66	4.77	4.32	4.22	4.08
	Non-Irrigated					
Alankar	2.51	2.69	3.67	3.36	3.23	3.09
PBM16	2.26	2.51	3.39	3.12	3.01	2.86
Mean	2.96	3.19	4.21	3.87	3.73	

	L.S.D. at 5%		
	Pod number	Seed yield	Oil yield
Irrigation (A)	NS	NS	NS
Cultivar (B)	0.35	0.07	0.09
A X B	NS	NS	NS
Spray (C)	0.17	NS	NS
A X C	NS	NS	NS
B X C	NS	NS	NS
A X B X C	NS	NS	NS

Table 72. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant height (cm plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	84.63	92.47	101.83	92.98	84.37	99.67	113.47	99.17
N_{40}	108.17	113.13	120.30	113.87	105.73	116.97	129.00	117.23
N_{60}	114.70	121.37	128.37	121.48	113.87	125.30	138.73	125.97
N_{80}	123.27	130.27	138.33	130.62	123.73	135.13	147.70	135.52
Mean	107.69	114.31	122.21		106.73	119.27	132.23	
	120				L.S.D. at 5%			
N_0	90.30	104.00	116.50	103.60		80	100	120
N_{40}	109.77	122.07	134.73	122.19	Spray (S)	0.83	0.76	0.98
N_{60}	119.37	131.13	143.67	131.39	Nitrogen (N)	0.96	0.88	1.14
N_{80}	128.73	140.63	152.93	140.77	S x N	1.66	1.53	NS
Mean	112.04	124.46	136.96					

Table 73. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area plant^{-1} (cm^2) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2249.33	2764.67	3243.33	2752.44	2381.67	3113.33	3777.00	3090.67
N_{40}	3260.33	3869.00	4425.33	3851.55	3501.33	4207.67	4968.33	4225.78
N_{60}	3833.00	4483.33	5095.00	4470.44	4312.67	5123.67	5946.67	5127.67
N_{80}	4625.67	5268.33	5817.00	5237.00	5203.67	6022.33	6790.00	6005.33
Mean	3412.08	4096.33	4645.17		3849.83	4616.75	5370.50	
	120						L.S.D. at 5%	
N_0	1313.33	1814.00	2311.00	1812.78		80	100	120
N_{40}	2030.00	2552.67	3082.33	2555.00	Spray (S)	24.38	23.66	23.66
N_{60}	2565.33	3107.00	3699.67	3124.00	Nitrogen (N)	28.15	27.32	27.32
N_{80}	3282.33	3826.67	4380.33	3829.78	S x N	48.77	47.33	47.31
Mean	2297.75	2825.08	3368.33					

Table 74. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area index of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2.81	3.46	4.05	3.44	2.98	3.89	4.72	3.86
N_{40}	4.07	4.84	5.53	4.81	4.38	5.26	6.21	5.28
N_{60}	4.79	5.60	6.37	5.59	5.39	6.40	7.43	6.41
N_{80}	5.78	6.59	7.27	6.55	6.50	7.53	8.49	7.51
Mean	4.36	5.12	5.80		4.81	5.77	6.71	
	120							
N_0	1.64	2.27	2.89	2.27				
N_{40}	2.54	3.19	3.85	3.19				
N_{60}	3.21	3.88	4.62	3.90				
N_{80}	4.10	4.78	5.47	4.78				
Mean	2.87	3.53	4.21					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.030	0.030	0.030
Nitrogen (N)	0.035	0.034	0.034
S x N	0.061	0.059	0.059

Table 75 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf area ($cm^2 g^{-1}$) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	280 46	296 00	309 18	295 21	387 89	420 33	443 83	417 35
N_{40}	296 39	315 33	324 43	312 05	414 85	435 67	453 31	434 61
N_{60}	315 73	325 00	332 57	324 43	428 27	446 00	460 98	445 08
N_{80}	325 52	333 00	340 17	332 90	440 98	457 00	470 87	456 28
Mean	304 52	317 33	326 59			439 75	457 25	
	120						L S D at 5%	
N_0	419 59	441 00	453 14	437 91		80	100	120
N_{40}	454 14	465 33	473 48	464 32	Spray (S)	0 67	0 67	0 88
N_{60}	471.56	478 33	485 52	478 49	Nitrogen (N)	0 76	0.77	1.02
N_{80}	486 99	492 33	496 09	491 80	S x N	NS	NS	NS
Mean		469 25	477 06					

Table 76 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf weight (mg cm ^{2}) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	3 56	3 37	3 23	3 39	2 58	2 38	2 25	2 40
N_{40}	3 37	3 17	3 08	3 21	2 41	2 29	2 20	2 30
N_{60}	3 17	3 07	3 01	3 08	2 33	2 24	2 17	2 25
N_{80}	3 07	3 00	2 94	3 00	2 27	2 19	2 12	2 19
Mean	3 29	3 15	3 06		2 40	2 27	2 18	
	120							
N_0	2 38	2 27	2 21	2 29				
N_{40}	2 20	2 15	2 11	2 15				
N_{60}	2 12	2 09	2 06	2 09				
N_{80}	2 05	2 03	2 01	2 03				
Mean	2 19	2 13	2 10					

	L S D at 5%		
	80	100	120
Spray (S)	0 006	0 005	0 005
Nitrogen (N)	0 007	0 006	0 006
S x N	NS	NS	NS

Table 77. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	25.35	29.18	32.59	29.04	28.45	32.34	35.68	32.16
N_{40}	33.68	37.22	40.92	37.27	36.78	40.33	43.99	40.37
N_{60}	35.81	39.90	43.97	39.89	39.77	43.83	47.87	43.82
N_{80}	39.67	43.53	47.03	43.41	44.77	48.63	52.12	48.51
Mean	33.63	37.46	41.13		37.44	41.28	44.92	
	120						L.S.D. at 5%	
N_0	32.84	36.39	39.81	36.35		80	100	120
N_{40}	40.84	44.39	48.09	44.44	Spray (S)	0.18	0.18	0.14
N_{60}	44.73	48.76	52.77	48.75	Nitrogen (N)	0.21	0.21	0.17
N_{80}	50.82	54.65	58.45	54.64	S x N	0.37	0.36	0.29
Mean	42.31	46.05	49.78					

Table 78. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	8.02	9.33	10.49	9.28	6.14	7.40	8.51	7.35
N_{40}	11.00	12.26	13.64	12.30	8.44	9.66	10.96	9.68
N_{60}	12.14	13.79	15.32	13.75	10.07	11.50	12.90	11.49
N_{80}	14.21	15.82	17.10	15.71	11.80	13.20	14.42	13.14
Mean	11.34	12.80	14.14		9.11	10.44	11.70	
	120							
N_0	3.13	4.12	5.10	4.12				
N_{40}	4.47	5.48	6.51	5.49				
N_{60}	5.44	6.49	7.62	6.52				
N_{80}	6.74	7.77	8.83	7.78				
Mean	4.94	5.97	7.02					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.08	0.06	0.05
Nitrogen (N)	0.09	0.06	0.06
S x N	0.15	0.11	NS

Table 79. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (g) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	15.37	17.25	18.86	17.16	17.96	19.48	20.84	19.43
N_{40}	19.36	20.92	22.50	20.93	21.77	23.09	24.38	23.08
N_{60}	19.75	21.36	23.07	21.39	22.20	23.64	25.11	23.65
N_{80}	20.45	22.04	23.64	22.04	23.89	25.25	26.54	25.23
Mean	18.74	20.39	22.02		21.45	22.87	24.22	
	120							
N_0	22.49	23.76	24.99	23.75			L.S.D. at 5%	
N_{40}	26.55	27.80	29.08	27.81		80	100	120
N_{60}	27.86	29.28	30.68	29.28	Spray (S)	0.09	0.09	0.06
N_{80}	30.24	31.54	32.80	31.53	Nitrogen (N)	0.11	0.11	0.07
Mean	26.79	28.10	29.39		S x N	NS	NS	0.11

Table 80. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (g) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	1.95	2.60	3.24	2.60	4.35	5.45	6.43	5.41
N_{40}	3.32	4.04	4.78	4.05	6.58	7.58	8.66	7.60
N_{60}	3.92	4.78	5.58	4.76	7.50	8.69	9.86	8.69
N_{80}	5.01	5.68	6.29	5.66	9.08	10.18	11.15	10.14
Mean	3.55	4.28	4.97		6.88	7.98	9.03	
	120							
N_0	7.22	8.51	9.72	8.49				
N_{40}	9.83	11.10	12.50	11.14				
N_{60}	11.43	12.98	14.47	12.96				
N_{80}	13.84	15.34	16.82	15.33				
Mean	10.58	11.98	13.38					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.03	0.04	0.06
Nitrogen (N)	0.04	0.05	0.06
S x N	0.06	0.09	0.11

Table 81. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	31.64	31.97	32.19	31.93	21 58	22 90	23.85	22.78
N_{40}	32.66	32.94	33.33	32.98	22.95	23 95	24.91	23.94
N_{60}	33.90	34.53	34.84	34.42	25 32	26 24	26.95	26 02
N_{80}	35.82	36.33	36.36	36.17	26.36	27.15	27.96	27.16
Mean	33.50	33.94	34.18		24.05	25.06	25.92	
	120				L.S.D. at 5%			
N_0	9.52	11.32	12.81	11.22		80	100	120
N_{40}	10.94	12.35	13.54	12.28	Spray (S)	0.07	0.06	0.08
N_{60}	12.16	13.32	14.44	13.31	Nitrogen (N)	0.08	0.07	0.09
N_{80}	13.26	14.22	15.11	14.20	S x N	0.15	0.12	NS
Mean	11.47	12.80	13.97					

Table 82. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	60.63	59.12	57.87	59.21	63.13	60.25	58.41	60.60
N_{40}	57.48	56.20	54.98	56.22	59.19	57.25	55.42	57.29
N_{60}	55.15	53.49	52.47	53.70	57.82	53.92	52.45	54.73
N_{80}	51.55	50.62	50.26	50.81	53.36	51.92	50.92	52.09
Mean	56.20	54.86	53.89		58.37	55.84	54.30	
	120				L.S.D. at 5%			
N_0	68.48	65.28	62.77	66.51		80	100	120
N_{40}	65.01	62.64	60.49	62.71	Spray (S)	0.10	0.10	0.11
N_{60}	62.28	60.06	58.14	60.16	Nitrogen (N)	0.12	0.11	0.13
N_{80}	60.14	57.72	56.12	57.99	S x N	0.21	0.19	NS
Mean	63.98	61.43	59.38					

Table 83. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	7.69	8.91	9.94	8.85	15.29	16.85	18.02	16.72
N_{40}	9:85	10.85	11.68	10.79	17.89	18.79	19.68	18.79
N_{60}	10.94	11.98	12.69	11.87	19.61	19.83	20.60	20.01
N_{80}	12.63	13.04	13.37	13.01	20.28	20.93	21.39	20.87
Mean	10.28	11.20	11.92		18.27	19.10	19.92	
	120				L.S.D. at 5%			
N_0	21.90	23.39	24.41	23.23		80	100	120
N_{40}	24.07	25.01	26.00	25.02	Spray (S)	0.05	0.05	0.06
N_{60}	25.55	26.62	27.42	26.53	Nitrogen (N)	0.05	0.06	0.07
N_{80}	27.23	28.06	28.78	28.02	S x N	0.09	0.10	0.13
Mean	24.71	25.77	58.45					

Table 84 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf fresh weight (g plant ^{1}) of mustard (*Brassica juncea* L) cultivar Alankai grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	34 67	41 34	47 34	41 12	25 26	30 58	35 26	30 37
N_{40}	49 77	56 22	63 45	56 48	36 26	41 43	47 50	41 73
N_{60}	56 08	64 43	72 37	64 29	44 14	50 39	56 48	50 34
N_{80}	66 77	75 38	82 06	74 74	52 82	59 11	64 39	58 77
Mean	51 82	59 34	66 31		39 62	45 38	50 91	
	120						L S D at 5%	
N_0	12 32	16 17	20 02	16 17		80	100	120
N_{40}	18 41	22 41	26 51	22 45	Spray (S)	0 47	0 33	0 23
N_{60}	22 86	27 09	31 70	27 22	Nitrogen (N)	0 54	0 38	0 26
N_{80}	28 22	32 37	36 66	32 42	S x N	0 94	0 65	NS
Mean	20 45	24 51	28 73					

Table 85. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf turgid weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	53.05	59.71	65.46	59.41	45.33	50.34	54.29	49.99
N_{40}	70.30	76.37	83.68	76.78	58.61	63.27	69.07	63 65
N_{60}	76.09	84.79	92.77	84.55	68 18	74.18	79.95	74.10
N_{80}	86.54	94.90	101.32	94.25	77.42	83.16	87.77	82.78
Mean	71.49	78.94	85.81		62.38	67.74	72.77	
	120						L.S.D. at 5%	
N_0	25.20	29.25	3.20	29.22		80	100	120
N_{40}	33.38	37.56	41.81	37.58	Spray (S)	0.50	0.50	0.34
N_{60}	39.40	43.83	48.76	44.00	Nitrogen (N)	0.57	0.58	0.39
N_{80}	46.31	50.50	54.89	50.57	S x N	0.99	1.00	NS
Mean	36.07	40.29	44.67					

Table 86 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf relative water content (%) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	59 02	63 53	67 04	63 20	48 84	53 97	58 43	53 75
N_{40}	65 38	68 57	71.12	68 36	55 45	59 25	62 88	59 19
N_{60}	68 74	71 32	73.66	71 24	58 63	62 03	65.00	61 88
N_{80}	72.66	75 32	77.13	75 04	62 51	65 60	68.12	65.41
Mean	66.45	69.69	72.24		56 38	60 21	63.61	
	120						L.S.D. at 5%	
N_0	40.36	47.96	52.53	46.95		80	100	120
N_{40}	48.22	52.74	56.66	52.54	Spray (S)	0.35	0.10	0.16
N_{60}	51.29	55.20	58.11	54.87	Nitrogen (N)	0 40	0.12	0.19
N_{80}	54.28	57.58	58.76	56.87	S x N	NS	NS	NS
Mean	48 54	53 37	56 51					

Table 87. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on rate of photosynthesis ($\mu mol\ m^{-2}s^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	15.10	17.47	19.87	17.48	13.14	15.58	17.94	15.55
N_{40}	18.24	20.96	24.07	21.09	16.16	19.13	22.06	19.12
N_{60}	21.00	23.93	26.64	23.86	19.23	22.25	25.27	22.25
N_{80}	23.14	25.73	28.32	25.73	22.15	24.90	27.43	24.83
Mean	19.37	22.02	24.73		17.67	20.47	23.17	

L.S.D. at 5%

	80	100
Spray (S)	0.15	0.23
Nitrogen (N)	0.18	0.26
S x N	0.31	0.45

Table 88 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stomatal conductance (mol $m^{-2}s^{-1}$) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	0 42	0.44	0.46	0.44	0 40	0 41	0.43	0 41
N_{40}	0 45	0 47	0 49	0 47	0.43	0 45	0.47	0 45
N_{60}	0 48	0.50	0 52	0.50	0.46	0 48	0 51	0.48
N_{80}	0.51	0.53	0 55	0 53	0 50	0 52	0 54	0 52
Mean	0.46	0.48	0 50		0 45	0 47	0 49	

	L S D. at 5%	
	80	100
Spray (S)	0 004	0.005
Nitrogen (N)	0 005	0.005
S x N	NS	NS

Table 89 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on internal carbon dioxide concentration of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	257 80	272 47	287 60	272 62	240 97	257 30	272 27	256 84
N_{40}	291 60	310 50	333 53	311 88	272 50	294 90	315 53	294 31
N_{60}	324 23	345 53	365 10	344 96	308 73	330 83	351 57	330 38
N_{80}	351 37	368 50	384 63	368 17	342 23	361 23	377 13	360 20
Mean	306 25	324 25	342 72		291 11	311 07	329 13	

	L S D at 5%	
	80	100
Spray (S)	1 99	2 56
Nitrogen (N)	2 30	2 95
S x N	3 99	5 12

Table 90 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on transpiration rate (kg m^{-2} day^{-1}) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	11 92	12 34	12 71	12 32	9 18	9 61	9 97	9 59
N_{40}	12 89	13 25	13 60	13 24	10 60	10 97	11 32	10 96
N_{60}	13 17	13 69	14 11	13 66	10 84	11 29	11 72	11 28
N_{80}	13 81	14 23	14 59	14 21	11 38	11 74	12 07	11 73
Mean	12 95	13 38	13 75		10 50	10 90	11 27	

	L S D at 5%	
	80	100
Spray (S)	0 04	0 03
Nitrogen (N)	0 04	0 03
S x N	0 08	0 06

Table 91 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on carboxylation efficiency (%) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	5 85	6 41	6 91	6 39	5 45	6 05	6 59	6 03
N_{40}	6 28	6 74	7 22	6 74	5 93	6 48	6 99	6 47
N_{60}	6 48	6 92	7 30	6 90	6 23	6 72	7 19	6 71
N_{80}	6 58	6 98	7 36	6 97	6 47	6 88	7 27	6 87
Mean	6 29	6 76	7 20		6 02	6 54	7 01	

	L S D at 5%	
	80	100
Spray (S)	0 05	0 05
Nitrogen (N)	0 05	0 06
S x N	NS	NS

Table 92. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on photosynthetic water use efficiency (μmol mol^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	35.95	39.69	43.19	39.61	32.85	37.69	41.72	37.42
N_{40}	40.35	44.59	49.12	44.69	37.58	42.82	46.94	42.45
N_{60}	43.75	47.54	51.23	47.50	41.80	46.03	49.55	44.62
N_{80}	45.37	48.86	51.49	48.57	44.30	47.59	50.79	47.56
Mean	41.35	45.17	48.76		39.13	43.53	47.25	

L.S.D. at 5%

	80	100
Spray (S)	0.34	0.37
Nitrogen (N)	0.39	0.43
S x N	0.67	NS

Table 93. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on water use efficiency (mg g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2.13	2.37	2.56	2.35	3.10	3.36	3.58	3.35
N_{40}	2.61	2.80	3.00	2.80	3.47	3.68	3.75	3.63
N_{60}	2.72	2.91	3.12	2.92	3.67	3.88	4.08	3.88
N_{80}	2.87	3.06	3.22	3.05	3.93	4.14	4.32	4.13
Mean	2.58	2.79	2.97		3.54	3.77	3.93	

	L.S.D. at 5%	
	80	100
Spray (S)	0.01	0.01
Nitrogen (N)	0.01	0.01
S x N	NS	NS

Table 94. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on 1-aminocyclopropane-1-carboxylic acid (ACC) (η mol g fresh weight^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	17.27	19.77	22.19	19.74	19.56	22.32	24.75	22.21
N_{40}	20.99	23.24	26.01	23.41	23.72	26.09	29.05	26.29
N_{60}	24.50	26.99	29.41	26.96	26.92	30.15	32.94	30.00
N_{80}	28.07	30.78	33.16	30.67	31.31	33.89	37.02	34.07
Mean	22.71	25.19	27.69		25.38	28.11	30.94	

	L.S.D. at 5%	
	80	100
Spray (S)	0.12	0.22
Nitrogen (N)	0.14	0.25
S x N	NS	0.43

Table 95. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on ACC oxidase (η L g^{-1} fresh weight h^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	57.98	63.85	69.75	63.86	70.21	78.56	87.07	78.61
N_{40}	80.05	80.01	89.75	83.27	95.28	105.44	114.02	104.91
N_{60}	89.50	97.26	104.96	97.24	108.10	116.54	124.99	116.55
N_{80}	104.11	111.90	119.46	111.83	121.37	130.80	141.02	131.06
Mean	82.91	88.26	95.98		98.74	107.84	116.77	

	L.S.D. at 5%	
	80	100
Spray (S)	1.47	1.45
Nitrogen (N)	1.70	1.67
S x N	2.94	NS

Table 96. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on ethylene evolution (ηl h^{-1} $plant^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	9.27	11.15	12.02	10.81	11.98	13.12	15.00	13.37
N_{40}	17.94	17.60	19.14	18.23	19.43	21.17	22.82	21.14
N_{60}	21.97	24.00	25.83	23.93	25.22	26.98	29.04	27.08
N_{80}	28.89	30.59	32.75	30.74	32.32	34.36	36.05	34.24
Mean	19.52	20.84	22.43		22.24	23.91	25.73	

L.S.D. at 5%

	80	100
Spray (S)	0.48	0.50
Nitrogen (N)	0.55	0.58
S x N	NS	NS

Table 97. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrate reductase activity (μ mol NO_2^- g^{-1} h^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	0.14	0.17	0.20	0.17	0.22	0.22	0.26	0.23
N_{40}	0.40	0.40	0.42	0.40	0.44	0.46	0.49	0.46
N_{60}	0.46	0.49	0.53	0.49	0.53	0.56	0.62	0.57
N_{80}	0.58	0.62	0.64	0.61	0.67	0.70	0.73	0.70
Mean	0.39	0.42	0.45		0.46	0.49	0.53	

	L.S.D. at 5%	
	80	100
Spray (S)	0.01	0.01
Nitrogen (N)	0.01	0.01
S x N	NS	NS

Table 98 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen content (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2.15	2.30	2.43	2.29	1.97	2.20	2.37	2.18
N_{40}	2.46	2.58	2 69	2 58	2 19	2 36	2 52	2 36
N_{60}	2.65	2.76	2 88	2 76	2 33	2 49	2 63	2 48
N_{80}	2 87	2 96	3 00	2 94	2 51	2 65	2 75	2 64
Mean	2 53	2.65	2 75		2 25	2 43	2 57	
	120						L.S.D. at 5%	
N_0	1.72	1.92	2.07	1.90		80	100	120
N_{40}	2.08	2 19	2 27	2.18	Spray (S)	0 01	0.01	0.01
N_{60}	2.15	2.25	2.32	2.24	Nitrogen (N)	0.02	0.01	0.01
N_{80}	2.21	2 29	2.35	2.28	S x N	0.03	NS	0 02
Mean	2 04	2.16	2.25					

Table 99 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen accumulation (mg plant^{-1}) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	544 33	672 00	791 67	669 33	561 67	712 33	846 67	706 89
N_{40}	829 33	960 33	1099 67	963 11	806 67	953 00	1105 33	955 00
N_{60}	947 67	1099 67	1266 00	1104 44	927 67	1093 00	1257 67	1092 78
N_{80}	1140 00	1289 67	1411 67	1280 44	1123 67	1288 67	1434 67	1282 33
Mean	865 33	1005 42	1142 25		854 92	1011 75	1161 08	
	120							
N_0	566 67	700 00	826 33	697 67				
N_{40}	849 67	970 33	1093 67	971 22				
N_{60}	964 33	1096 67	1226 33	1095 78				
N_{80}	1121 67	1257 33	1375 33	1251 44				
Mean	875 58	1006 08	1130 42					

	L S D at 5%		
	80	100	120
Spray (S)	6 50	7 40	4 90
Nitrogen (N)	7 50	8 54	5 66
S x N	12 99	14 79	NS

Table 100. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on number of pod plant^{-1}, number of seeds pod^{-1} and 1000 seed weight (g) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Pods plant^{-1}				Seeds pod^{-1}			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	138.00	146.33	153.33	145.89	12.45	13.23	13.95	13.21
N_{40}	159.30	166.33	173.00	166.22	13.83	14.52	15.23	14.53
N_{60}	172.67	181.67	189.00	181.44	15.10	15.82	16.52	15.82
N_{80}	190.33	197.33	203.67	197.11	16.36	17.07	17.76	17.06
Mean	165.07	172.92	179.75		14.44	15.16	15.86	

	1000 seed weight			
N_0	4.28	4.41	4.51	4.40
N_{40}	4.46	4.52	4.56	4.51
N_{60}	4.61	4.62	4.63	4.62
N_{80}	4.70	4.69	4.69	4.69
Mean	4.51	4.56	4.60	

L.S.D. at 5%

	Pods plant^{-1}	Seeds pod^{-1}	1000 seed weight
Spray (S)	0.71	0.05	0.01
Nitrogen (N)	0.82	0.06	0.01
S x N	NS	NS	NS

Table 101. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on seed yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Seed yield				Biological yield			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	9.19	10.67	12.05	10.64	42.81	45.49	48.01	45.44
N_{40}	12.27	13.65	15.00	13.64	52.80	55.49	58.36	55.55
N_{60}	15.03	16.58	18.07	16.56	57.67	60.95	64.22	60.94
N_{80}	18.29	19.74	21.20	19.74	65.27	68.31	71.28	68.29
Mean	13.70	15.16	16.58		54.64	57.56	60.47	
	Harvest index							
N_0	21.46	23.44	25.10	23.33			L.S D. at 5%	
N_{40}	23.24	24.60	25.70	24.51		Seed yield	Biological yield	Harvest index
N_{60}	26.06	27.20	28.13	27.13	Spray (S)	0.08	0.18	0.08
N_{80}	28.02	28.90	29.74	28.89	Nitrogen (N)	0.09	0.21	0.09
Mean	24.69	26.04	27.17		S x N	NS	0.36	0.16

Table 102. Effect of ethrel spray at 60d (post flowering stage) on seed nitrogen content (mg g^{-1} $plant^{-1}$), nitrogen harvest index and nitrogen yield potential of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Seed nitrogen content				Nitrogen harvest index			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	32.37	40.07	46.73	39.72	0.06	0.06	0.06	0.06
N_{40}	43.37	50.07	56.50	49.98	0.05	0.05	0.05	0.05
N_{60}	45.73	52.07	58.93	52.24	0.05	0.05	0.05	0.05
N_{80}	50.30	58.50	65.07	57.96	0.05	0.05	0.05	0.05
Mean	42.94	50.18	56.81		0.05	0.05	0.05	

	Nitrogen yield merit			
N_0	1.94	2.40	2.80	2.38
N_{40}	2.17	2.50	2.82	2.50
N_{60}	2.29	2.60	2.95	2.61
N_{80}	2.51	2.92	3.25	2.89
Mean	2.23	2.61	2.95	

	L.S.D. at 5%		
	Seed nitrogen content	Nitrogen harvest index	Nitrogen yield potential
Spray (S)	0.17	NS	0.01
Nitrogen (N)	0.20	NS	0.01
S x N	0.35	NS	0.02

Table 103. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on oil yield (q ha^{-1}) and oil content (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Oil yield				Oil content			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	3.27	3.94	4.60	3.94	35.55	36.92	38.21	36.89
N_{40}	4.29	4.95	5.63	4.96	34.99	36.26	37.52	36.26
N_{60}	5.12	5.85	6.61	5.86	34.07	35.31	36.60	35.33
N_{80}	6.02	6.78	7.55	6.78	32 94	34.32	35.61	34.29
Mean	4.67	5.38	6.10		34 39	35 70	36.99	

L.S.D. at 5%

	Oil yield	Oil content
Spray (S)	0.04	0.06
Nitrogen (N)	0.04	NS
S x N	NS	NS

Table 104. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on acid value, iodine value and saponification value of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Acid value				Iodine value			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	3.58	3.90	4.21	3.90	100.12	102.40	104.07	102.19
N_{40}	3.36	3.74	4.04	3.71	98.75	100.83	102.39	100.66
N_{60}	3.03	3.41	3.76	3.40	97.07	98.89	100.30	98.75
N_{80}	2.81	3.12	3.44	3.12	95.70	97.50	98.93	97.37
Mean	3.19	3.54	3.86		97.91	99.91	101.42	

Saponification value				L.S.D. at 5%			
N_0	143.19	146.15	149.47	146.27		Acid value	Iodine value	Saponification value
N_{40}	149.91	152.95	155.53	152.80				
N_{60}	152.87	156.42	159.29	156.19	Spray (S)	0.04	0.17	0.31
N_{80}	156.77	159.83	162.73	159.78	Nitrogen (N)	NS	NS	NS
Mean	150.69	153.84	156.76		S x N	NS	NS	NS

Table 105. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant height (cm plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	58.33	62.83	68.23	63.13	61.60	68.93	75.73	68.76
N_{40}	75.73	80.87	85.93	80.84	77.27	84.87	91.93	84.69
N_{60}	83.63	90.13	96.10	89.96	86.73	94.13	101.70	94.19
N_{80}	94.37	100.93	106.43	100.58	97.37	103.90	112.70	104.66
Mean	78.02	83.69	89.18		80.74	87.96	95.52	
	120						L.S.D. at 5%	
N_0	71.20	75.17	81.03	75.80		80	100	120
N_{40}	84.97	89.77	95.77	90.17	Spray (S)	0.61	0.82	0.95
N_{60}	92.13	99.00	106.10	99.08	Nitrogen (N)	0.71	0.94	1.10
N_{80}	103.87	110.27	117.10	110.41	S x N	1.23	NS	NS
Mean	88.04	93.55	100.00					

Table 106. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area (cm^2 $plant^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	1627.67	2072.33	2497.00	2065.67	1905.33	2414.00	2883.00	2400.78
N_{40}	2393.33	2837.00	3266.00	2832.11	2711.00	3198.00	3706.67	3205.22
N_{60}	2708.67	3177.00	3644.67	3176.78	3136.33	3662.00	4174.67	3657.67
N_{80}	3118.67	3586.33	4053.00	3586.00	3628.67	4138.33	4646.00	4137.67
Mean	2462.08	2918.17	3365.17		2845.33	3353.08	3852.58	
	120						L.S.D. at 5%	
N_0	953.00	1353.67	1717.67	1341.44		80	100	120
N_{40}	1454.33	1825.00	2220.00	1833.11	Spray (S)	21.19	19.84	14.56
N_{60}	1888.00	2297.33	2683.33	2289.56	Nitrogen (N)	24.47	22.91	16.82
N_{80}	2380.00	2740.00	3129.67	2749.89	S x N	NS	NS	NS
Mean	1668.83	2054.00	2437.62					

Table 107. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf area index of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2.03	2.59	3.12	2.58	2.26	3.02	3.73	3.00
N_{40}	2.99	3.55	4.08	3.54	3.26	4.00	4.75	4.01
N_{60}	3.38	3.97	4.55	3.97	3.79	4.58	5.34	4.57
N_{80}	3.89	4.48	5.06	4.48	4.41	5.17	4.94	5.17
Mean	3.07	3.65	4.20		3.43	4.19	4.32	
	120						L.S.D. at 5%	
N_0	1.19	1.69	2.15	1.68		80	100	120
N_{40}	1.82	2.28	2.77	2.29	Spray (S)	0.03	0.02	0.02
N_{60}	2.36	2.87	3.35	2.86	Nitrogen (N)	0.03	0.03	0.02
N_{80}	2.97	3.43	3.91	3.44	S x N	NS	NS	NS
Mean	2.08	2.57	3.04					

Table 108. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf area (cm^2g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	248.50	264.67	276.83	263.33	359.56	387.00	404.20	383.59
N_{40}	274.46	286.00	293.70	284.72	386.24	403.00	416.03	401.76
N_{60}	2.86.93	294.33	302.96	294.74	397.95	412.33	423.65	411.31
N_{80}	299.87	306.33	312.25	306.32	409.13	421.00	430.67	420.27
Mean	277.44	287.83	296.43		388.22	405.83	418.64	
	120						L.S.D. at 5%	
N_0	370.82	411.67	418.18	400.22		80	100	120
N_{40}	390.95	429.33	449.39	423.22	Spray (S)	0.69	0.66	0.67
N_{60}	419.55	440.67	457.13	439.12	Nitrogen (N)	0.79	0.77	0.77
N_{80}	435.90	453.00	467.11	452.00	S x N	NS	NS	NS
Mean	404.30	433.67	447.95					

Table 109. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on specific leaf weight (mg cm^{-2}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	4.02	3.78	3.61	3.80	2.78	2.58	2.47	2.61
N_{40}	3.64	3.50	3.40	3.51	2.59	2.48	2.40	2.49
N_{60}	3.48	3.40	3.30	3.39	2.51	2.42	2.36	2.43
N_{80}	3.33	3.26	3.20	3.26	2.44	2.37	2.32	2.38
Mean	3.62	3.48	3.38		2.58	2.46	2.39	
	120						L.S.D. at 5%	
N_0	2.70	2.43	2.28	2.47		80	100	120
N_{40}	2.56	2.33	2.22	2.37	Spray (S)	0.008	0.009	0.004
N_{60}	2.38	2.27	2.19	2.28	Nitrogen (N)	0.009	0.011	0.005
N_{80}	2.29	2.20	2.14	2.21	S x N	NS	NS	NS
Mean	2.48	2.31	2.21					

Table 110. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	21.56	25.25	28.69	25.17	24.64	28.38	31.79	28.27
N_{40}	27.65	31.06	34.41	31.04	30.78	34.10	37.66	34.18
N_{60}	29.16	32.82	36.26	32.75	33.28	36.93	40.39	36.87
N_{80}	31.03	34.49	37.96	34.49	36.13	39.56	43.02	39.57
Mean	27.35	30.90	34.33		31.21	34.74	38.22	
	120							
N_0	27.71	31.44	34.85	31.33				
N_{40}	34.03	37.21	40.81	37.35				
N_{60}	38.47	42.11	45.48	42.02				
N_{80}	42.28	45.64	49.16	45.69				
Mean	35.62	39.10	42.57					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.15	0.16	0.15
Nitrogen (N)	0.17	0.18	0.18
S x N	NS	NS	NS

Table 111. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	6.55	7.83	9.02	7.80	5.02	6.23	7.38	6.21
N_{40}	8.72	9.92	10.12	9.92	6.76	7.93	9.15	7.95
N_{60}	9.444	10.79	12.03	10.75	7.63	8.88	10.09	8.87
N_{80}	10.40	11.71	12.98	11.70	8.62	9.83	11.02	9.82
Mean	8.78	10.06	11.29		7.01	8.22	9.41	
	120						L.S.D. at 5%	
N_0	2.57	3.29	3.92	3.26		80	100	120
N_{40}	3.72	4.25	4.94	4.27	Spray (S)	0.06	0.05	0.03
N_{60}	4.50	5.21	5.87	5.19	Nitrogen (N)	0.07	0.06	0.04
N_{80}	5.46	6.04	6.70	6.07	S x N	NS	NS	0.07
Mean	4.04	4.70	5.36					

Table 112. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	13.62	15.41	17.05	15.36	16.10	17.61	18.93	17.55
N_{40}	16.73	18.30	19.85	18.29	19.15	20.38	21.74	20.42
N_{60}	17.14	18.75	20.27	18.73	20.02	21.39	22.70	21.37
N_{80}	17.54	19.09	20.67	19.10	21.06	22.35	23.67	22.36
Mean	16.26	17.89	19.46		19.08	20.43	21.76	
	120							
N_0	19.40	21.14	22.76	21.10				
N_{40}	22.86	24.28	25.99	24.38				
N_{60}	25.06	26.69	28.24	26.67				
N_{80}	26.46	28.04	29.71	28.07				
Mean	23.45	25.04	26.67					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.06	0.08	0.08
Nitrogen (N)	0.07	0.09	0.09
S x N	0.13	NS	NS

Table 113. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	1.39	2.01	2.63	2.01	3.51	4.53	5.49	4.51
N_{40}	2.31	2.84	3.44	2.86	4.87	5.79	6.77	5.81
N_{60}	2.58	3.28	3.94	3.26	5 63	6.63	7.59	6.62
N_{80}	3.08	3.69	4.31	3.70	6.44	7.38	8.33	7.39
Mean	2.34	2.95	3.58		5.12	6.08	7.44	
	120						L.S.D. at 5%	
N_0	5.74	7.01	8.17	6.98		80	100	120
N_{40}	7.55	8.65	9.89	8.70	Spray (S)	0.04	0.04	0.05
N_{60}	8.91	10.20	11.37	10.16	Nitrogen (N)	0.04	0.05	0.06
N_{80}	10.50	11.56	12.75	11.60	S x N	NS	NS	0.10
Mean	8.17	9.36	10.54					

Table 114. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	30.38	31.00	31.44	30.94	20.37	21.96	23.21	21.85
N_{40}	31.54	31.94	32.32	31.93	21.96	23.26	24.30	23.17
N_{60}	32.37	32.89	33.18	32.81	22.93	24.05	24.98	23.99
N_{80}	33.51	33.94	34.19	33.88	23.86	24.84	25.61	24.77
Mean	31.95	32.44	32.78		22.28	23.53	24.52	
	120						L.S.D. at 5%	
N_0	9.28	10.45	11.39	10.39		80	100	120
N_{40}	10.93	11.42	12.10	11.43	Spray (S)	0.08	0.08	0.06
N_{60}	11.70	12.38	12.91	12.36	Nitrogen (N)	0.09	0.09	0.07
N_{80}	12.91	13.24	13.63	13.27	S x N	NS	NS	0.12
Mean	11.20	11.87	12.51					

Table 115. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stem dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	63.17	61.03	59.43	61.21	65.34	62.06	59.55	62.32
N_{40}	60.50	58.92	57.69	59.03	62.21	59.43	57.73	59.79
N_{60}	58.78	57.12	55.90	57.27	60.16	57.92	56.20	58.09
N_{80}	56.52	55.35	54.45	55.44	58.29	56.50	55.02	56.60
Mean	59.74	58.11	56.87		61.50	58.98	57.12	
	120							
N_0	70.01	67.24	65.31	67.52				
N_{40}	67.18	65.30	63.68	65.39				
N_{60}	65.14	63.39	62.09	63.54				
N_{80}	62.58	61.43	60.43	61.48				
Mean	66.23	64.34	62.88					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.14	0.16	0.10
Nitrogen (N)	0.16	0.18	0.12
S x N	NS	NS	0.21

Table 116. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on pod dry weight (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	6.45	7.96	9.17	7.86	14.24	15.97	17.27	15.83
N_{40}	8.35	9.14	10.00	9.16	15.82	16.97	17.98	16.92
N_{60}	8.85	9.98	10.85	9.89	17.52	17.94	18.79	18.08
N_{80}	9.923	10.71	11.35	10.66	17.82	18.67	19.36	18.62
Mean	8.39	9.45	10.34		16.35	17.39	18.35	
	120						L.S.D. at 5%	
N_0	20.71	22.30	23.44	22.15		80	100	120
N_{40}	22.19	23.26	24.23	23.23	Spray (S)	0.08	0.06	0.05
N_{60}	23.16	24.22	25.00	24.13	Nitrogen (N)	0.09	0.07	0.06
N_{80}	24.83	25.33	25.93	25.36	S x N	NS	0.12	0.11
Mean	22.72	23.78	24.65					

Table 117. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf fresh weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	23.84	29.24	34.35	29.14	16.26	21.40	26.12	21.26
N_{40}	33.56	38.66	43.94	38.72	24.11	28.94	34.14	29.06
N_{60}	37.30	43.02	48.34	42.89	28.10	33.25	33.38	33.24
N_{80}	41.34	47.15	52.74	47.08	32.13	36.87	42.16	37.06
Mean	34.01	39.52	44.84		25.15	30.12	35.20	
	120				L.S.D. at 5%			
N_0	6.96	9.69	12.13	9.59		80	100	120
N_{40}	11.05	13.55	16.27	13.62	Spray (S)	0.26	0.24	0.12
N_{60}	14.07	16.95	19.76	16.93	Nitrogen (N)	0.30	0.28	0.13
N_{80}	17.66	20.16	23.02	20.28	S x N	NS	NS	0.23
Mean	12.43	15.09	17.80					

Table 118. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf turgid weight (g plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	46.46	52.46	57.71	52.21	37.93	43.63	48.66	43.41
N_{40}	58.70	63.98	69.30	63.99	48.36	53.55	59.01	53.64
N_{60}	62.29	68.47	74.08	68.28	53.41	59.05	64.47	58.98
N_{80}	66.66	72.58	78.27	72.50	58.53	63.24	69.13	63.63
Mean	58.53	64.37	69.84		49.56	54.87	60.32	
	120						L.S.D. at 5%	
N_0	19.23	23.83	27.77	23.61		80	100	120
N_{40}	26.07	29.96	34.28	30.10	Spray (S)	0.41	0.41	0.24
N_{60}	31.73	36.24	40.32	36.10	Nitrogen (N)	0.47	0.48	0.27
N_{80}	37.55	41.09	45.16	41.27	S x N	NS	NS	0.48
Mean	28.65	32.78	36.88					

Table 119. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on leaf relative water content (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	43.40	47.98	52.02	47.80	34.00	40.56	45.40	39.99
N_{40}	49.70	53.16	56.41	53.09	41.71	46.06	50.12	45.96
N_{60}	52.71	55.88	58.52	55.70	44.71	48.58	52.02	48.44
N_{80}	54.97	58.23	60.46	57.89	47.10	50.69	53.59	50.46
Mean	50.19	53.81	56.85		41.88	46.47	50.28	
	120						L.S.D. at 5%	
N_0	26.35	31.16	34.28	30.60		80	100	120
N_{40}	32.70	36.17	38.62	35.83	Spray (S)	0.12	0.20	0.12
N_{60}	35.14	37.84	40.32	37.77	Nitrogen (N)	0.14	0.23	0.14
N_{80}	38.02	40.27	42.43	40.24	S x N	0.24	NS	0.24
Mean	33.05	36.36	38.91					

Table 120. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on rate of photosynthesis ($\mu mol\ m^{-2}s^{-1}$) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	13.14	15.60	17.94	15 56	11.62	14 04	16.62	14.09
N_{40}	16.19	19.06	22.14	19 13	14.45	17 23	20.38	17.35
N_{60}	19.12	22.15	25.07	22.11	17.34	20.29	23.22	20.28
N_{80}	21.89	24.71	27.21	24 60	20 19	23 26	26.14	23.20
Mean	17.58	20.38	23099		15.90	18 71	21 59	

	L S D. at 5%	
	80	100
Spray (S)	0.18	0.14
Nitrogen (N)	0.21	0.16
S x N	0 36	0 28

Table 121. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on stomatal conductance (mol $m^{-2}s^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	0.40	0.41	0.43	0.41	0.37	0.39	0.41	0.39
N_{40}	0.43	0.45	0.47	0.45	0.41	0.43	0.45	0.43
N_{60}	0.47	0.49	0.51	0.49	0.44	0.46	0.49	0.46
N_{80}	0.50	0.52	0.54	0.52	0.48	0.51	0.53	0.50
Mean	0.45	0.47	0.49		0.42	0.45	0.47	

	L.S.D. at 5%	
	80	100
Spray (S)	0.004	0.005
Nitrogen (N)	0.004	0.005
S x N	NS	NS

Table 122. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on internal carbon dioxide concentration of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	242.67	259.23	274.13	258.68	228.30	244.93	263.13	245.46
N_{40}	275.03	296.93	321.27	297.74	264.73	286.17	307.50	286.13
N_{60}	312.33	333.70	354.20	333.41	298.80	319.17	340.93	319.63
N_{80}	343.23	360.80	377.33	360.46	332.17	351.23	369.93	351.11
Mean	293.32	312.67	331.73		281.00	300.38	320.38	

L.S.D. at 5%

	80	100
Spray (S)	2.52	2.52
Nitrogen (N)	2.91	2.91
S x N	5.05	NS

Table 123. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on transpiration rate (kg m^{-2} day^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	10.98	11.38	11.72	11.36	8.39	8.93	9.37	8.90
N_{40}	11.59	11.93	12.34	11.95	9.54	9.98	10.44	9.99
N_{60}	11.92	12.39	12.78	12.36	9.877	10.34	10.76	10.32
N_{80}	11.65	12.72	13.07	12.71	10.07	10.51	10.95	10.51
Mean	11.71	12.10	12.48		9.47	9.94	10.38	

	L.S.D. at 5%	
	80	100
Spray (S)	0.03	0.02
Nitrogen (N)	0.04	0.03
S x N	NS	0.05

Table 124. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on carboxylation efficiency (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	5.41	6.01	6.54	5.99	5.09	5.73	6.32	5.71
N_{40}	5.89	6.42	6.89	6.40	5.46	6.02	6.63	6.04
N_{60}	6.12	6.63	7.08	6.61	5.80	6.36	6.81	6.32
N_{80}	6.38	6.83	7.21	6.81	6.08	6.62	7.07	6.59
Mean	5.95	6.47	6.93		5.61	6.18	6.71	

	L.S.D. at 5%	
	80	100
Spray (S)	0.06	0.04
Nitrogen (N)	0.07	0.04
S x N	NS	0.07

Table 125 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on photosynthetic water use efficiency (μmol mol^{-1}) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	32 85	38 06	41 72	37 54	31 38	35 98	40 54	35 97
N_{40}	37 65	42 05	47 11	42 27	35 24	40 07	45 29	40 20
N_{60}	40 68	45 51	49 16	45 12	39 41	43 80	47 39	43 53
N_{80}	43 78	47 44	50 39	47 20	42 06	45 90	49 32	45 76
Mean	38 74	43 26	47 09		37 02	41 44	45 63	

	L S D at 5%	
	80	100
Spray (S)	0 34	0 29
Nitrogen (N)	0 39	0 34
S x N	0 67	0 59

Table 126. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on plant water use efficiency (mg g^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	1.96	2.22	2.45	2 21	2.94	3 18	3.39	3.17
N_{40}	2 38	2.60	2.79	2.59	3.23	3.41	3.61	3.42
N_{60}	2.45	2.65	2.84	2.65	3.37	3.56	3.75	3.56
N_{80}	2.66	2.71	2.90	2.76	3.59	3 76	3.93	3.76
Mean	2.36	2.54	2.74		3.28	3.48	3.67	

	L.S.D. at 5%	
	80	100
Spray (S)	0.01	0.01
Nitrogen (N)	0.01	0.01
S x N	0.02	NS

Table 127. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on 1-aminocyclopropane-1-carboxylic acid (ACC) (η mol g fresh weight^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	20.63	23.04	25.81	23.16	23.58	26.06	28.61	26.08
N_{40}	24.23	26.74	29.40	26.79	28.04	30.63	33.03	30.57
N_{60}	27.76	30.80	34.26	30.94	31.60	34.90	37.30	34.60
N_{80}	32.80	35.76	38.56	35.70	36.43	39.12	41.98	39.18
Mean	26.36	29.08	32.01		29.91	32.68	35.23	

	L.S.D. at 5%	
	80	100
Spray (S)	0.25	0.18
Nitrogen (N)	0.29	0.20
S x N	0.51	0.35

Table 128. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on ACC oxidase (η l g^{-1} fresh weight h^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	71.40	78.29	83.80	77.84	82.56	85.22	97.49	88.42
N_{40}	94.01	100.68	109.39	101.36	106.65	109.13	121.26	112.35
N_{60}	109.35	115.35	122.63	115.78	116.94	125.12	134.72	125.60
N_{80}	119.69	129.46	137.08	128.83	131.26	142.18	154.71	142.72
Mean	98.68	105.95	113.23		109.35	115.41	127.05	

	L.S.D. at 5%	
	80	100
Spray (S)	1.29	1.89
Nitrogen (N)	1.49	2.19
S x N	NS	3.79

Table 129. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on ethylene evolution (ηl h^{-1} $plant^{-1}$) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	11.65	13.08	13.93	12.89	14.58	16.18	17.37	16.05
N_{40}	18.83	20.05	22.58	20.49	24.97	24.35	26.45	25.26
N_{60}	25.05	27.45	29.81	27.43	28.89	31.61	34.06	31.52
N_{80}	32.40	35.41	37.65	35.15	37.27	39.06	40.76	39.03
Mean	21.98	24.00	25.99		26.43	27.80	29.66	

	L.S.D. at 5%	
	80	100
Spray (S)	0.61	0.52
Nitrogen (N)	0.71	0.60
S x N	1.23	NS

Table 130. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrate reductase activity (μ mol NO_2^- g^{-1} h^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80 and 100 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	0.15	0.17	0.20	0.17	0.12	0.12	0.14	0.13
N_{40}	0.40	0.40	0.43	0.40	0.32	0.35	0.38	0.35
N_{60}	0.46	0.50	0.54	0.50	0.40	0.43	0.46	0.43
N_{80}	0.58	0.62	0.65	0.62	0.52	0.55	0.58	0.55
Mean	0.39	0.42	0.45		0.33	0.36	0.39	

	L.S.D. at 5%	
	80	100
Spray (S)	0.01	0.01
Nitrogen (N)	0.01	0.01
S x N	NS	NS

Table 131 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen content (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	1.93	2.15	2.31	2.13	1.57	1.95	2.22	1.91
N_{40}	2.27	2.42	2.57	2.42	1.99	2.26	2.49	2.25
N_{60}	2.46	2.61	2.75	2.61	2.12	2.36	2.57	2.35
N_{80}	2.74	2.82	2.87	2.81	2.23	2.47	2.68	2.46
Mean	2.35	2.50	2.62		1.98	2.26	2.49	
	120							
N_0	1.55	1.76	1.93	1.76				
N_{40}	1.72	1.86	2.01	1.86				
N_{60}	1.81	1.97	2.12	1.97				
N_{80}	1.99	2.12	2.22	2.11				
Mean	1.77	1.93	2.07					

L.S.D. at 5%			
	80	100	120
Spray (S)	0.012	0.008	0.012
Nitrogen (N)	0.013	0.009	0.014
S x N	0.023	NS	NS

Table 132. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on nitrogen accumulation (mg plant^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen at 80, 100 and 120 DAS

Nitrogen (kg/ha)	Sampling days (after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	415.67	541.67	661.67	539.67	387.00	552.33	707.33	548.89
N_{40}	627.33	750.67	885.00	754.33	612.00	771.67	937.00	773.56
N_{60}	719.00	857.33	996.67	857.67	704.33	872.67	1038.33	871.78
N_{80}	850.33	972.33	1091.33	971.33	817.33	977.00	1145.67	980.00
Mean	653.08	780.50	909.67		630.17	793.42	957.08	
	120						L.S.D. at 5%	
N_0	429.33	554.00	672.00	551.89		80	100	120
N_{40}	585.00	693.00	819.67	699.22	Spray (S)	5.61	4.48	6.21
N_{60}	696.33	829.33	962.33	829.33	Nitrogen (N)	6.48	5.17	7.17
N_{80}	841.67	967.67	1094.00	967.78	S x N	11.23	NS	12.42
Mean	638.08	761.08	887.00					

Table 133. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight (g) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Pods plant^{-1}				Seeds pod^{-1}			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	122.00	129.33	137.00	129.44	11.14	11.87	12.50	11.84
N_{40}	137.00	144.33	152.00	144.44	12.13	12.69	13.31	12.71
N_{60}	149.33	156.67	164.00	156.67	13.30	13.80	14.35	13.82
N_{80}	159.67	166.67	174.67	167.00	14.00	14.87	15.44	14.77
Mean	142.00	149.25	156.92		12.64	13.31	13.90	

	1000 seed weight			
N_0	4.13	4.32	4.45	4.30
N_{40}	4.37	4.48	4.55	4.47
N_{60}	4.49	4.57	4.61	4.56
N_{80}	4.49	4.66	4.66	4.60
Mean	4.37	4.51	4.57	

L.S.D. at 5%

	Pods plant^{-1}	Seeds pod^{-1}	1000 seed weight
Spray (S)	0.54	0.04	0.01
Nitrogen (N)	0.63	0.05	0.01
S x N	NS	0.08	NS

Table 134 Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on seed yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) of mustard (*Brassica juncea* L) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Seed yield				Biological yield			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	7.01	8.29	9.53	8.28	35 47	39.30	42.80	39 19
N_{40}	90.08	10.26	11 51	10.28	43 28	46 51	50 27	46 69
N_{60}	11.15	12 36	13 56	12 36	48 84	52 64	56 10	52 53
N_{80}	12 55	14 43	15 71	14 23	53 60	57.05	60.70	57 12
Mean	9.95	11 34	12.58		45.30	48.88	52.47	

	Harvest index			
N_0	19.76	21.10	22.27	21.04
N_{40}	20.98	22 05	22.90	21.98
N_{60}	22.83	23.48	24.17	23.49
N_{80}	23.41	25.29	25.88	24.86
Mean	21.74	22.98	23.80	

L S.D. at 5%

	Seed yield	Biological yield	Harvest index
Spray (S)	0 29	0.20	0.08
Nitrogen (N)	0.34	0.23	0.09
S x N	NS	NS	0.15

Table 135. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on seed nitrogen content (mg g^{-1} $plant^{-1}$), nitrogen harvest index and nitrogen yield merit of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Seed nitrogen content				Nitrogen harvest index			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	24.73	31.27	37.07	31.02	0.06	0.06	0.06	0.06
N_{40}	33.37	38.77	45.23	39.12	0.05	0.05	0.05	0.05
N_{60}	37.27	42.83	49.20	43.10	0.05	0.05	0.05	0.05
N_{80}	42.00	47.70	53.80	47.83	0.05	0.05	0.05	0.05
Mean	34.34	40.14	45.33		0.05	0.05	0.05	

	Nitrogen yield merit			
N_0	1.48	1.88	2.22	1.86
N_{40}	1.67	1.94	2.26	1.96
N_{60}	1.86	2.14	2.46	2.15
N_{80}	2.10	2.38	2.69	2.39
Mean	1.78	2.08	2.41	

L.S.D. at 5%

	Seed nitrogen content	Nitrogen harvest index	Nitrogen yield merit
Spray (S)	0.23	NS	0.01
Nitrogen (N)	0.27	NS	0.01
S x N	0.46	NS	0.03

Table 136. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on oil yield (q ha^{-1}) and oil content (%) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Oil yield				Oil content			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2.34	2.87	3.42	2.88	33.39	34.65	35.92	34.65
N_{40}	2.96	3.48	4.04	3.49	32.64	33.90	35.08	33.88
N_{60}	3.51	4.05	4.61	4.06	31.52	32.80	34.03	32.78
N_{80}	3.84	4.60	5.20	4 55	30.61	31.91	33.11	31.87
Mean	3.16	3.75	4.32		32.04	33.31	34.53	

L.S.D. at 5%

	Oil yield	Oil content
Spray (S)	0.02	0.07
Nitrogen (N)	0.03	NS
S x N	NS	NS

Table 137. Effect of ethrel spray at 60d after sowing (DAS, flowering stage) on acid value, iodine value and saponification value of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Acid value				Iodine value			
	Ethrel concentration (μL/L)							
	0	100	200	Mean	0	100	200	Mean
N_0	2.69	3.01	3.32	3.01	97.13	99.14	100.95	99.08
N_{40}	2.56	2.89	3.39	2.95	95.93	98.06	99.47	97.82
N_{60}	2.44	2.78	3.06	2.76	94.18	96.20	97.97	96.11
N_{80}	2.29	2.62	2.89	2.60	92.70	94.73	95.96	94.53
Mean	2.50	2.82	3.17		95.04	97.03	98.59	

	Saponification value			
N_0	138.96	141.96	145.17	142.03
N_{40}	144.97	147.82	150.52	147.77
N_{60}	148.58	151.33	154.58	151.49
N_{80}	151.81	154.72	153.61	154.71
Mean	146.08	148.96	151.97	

L.S.D. at 5%

	Acid value	Iodine value	Saponification value
Spray (S)	0.10	0.09	0.30
Nitrogen (N)	NS	NS	NS
S x N	NS	NS	NS

Table 138 Pooled analysis of plant dry weight in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)											
	80				100				120			
	Ethrel concentration (µL/L)											
	0	100	200	Mean	0	100	200	Mean	0	100	200	Mean
	Irrigated				Irrigated				Irrigated			
N_0	25 35	29 18	32 59	29 04	28 45	32 34	35 68	32 16	32 84	36 39	39 81	36 35
N_{40}	33 68	37 22	40 92	37 27	36 78	40 33	43 99	40 37	40 84	44 39	48 09	44 44
N_{60}	35 81	39 90	43 97	39 89	39 77	43 83	47 87	43 71	44 73	48 76	52 77	48 75
N_{80}	39 67	43 53	47 03	43 41	44 77	48 63	52 12	48 51	50 82	54 65	58 45	54 64
	Non-Irrigated				Non-Irrigated				Non-Irrigated			
N_0	21 56	25 25	28 69	24 95	24 64	28 38	31 79	28 27	27 71	31 44	34 84	31 33
N_{40}	27 65	31 06	34 41	31 04	30 78	34 10	37 66	34 18	34 03	37 21	40 81	37 35
N_{60}	29 16	32 82	36 26	32 75	33 28	36 93	40 39	36 87	38 47	42 11	45 48	42 02
N_{80}	31 03	34 49	37 96	34 49	36 13	39 56	43 02	39 57	42 28	45 64	49 16	45 69
Mean	*30 49*	*34 18*	*37 73*		*34 32*	*38 01*	*41 56*		38 96	42 57	46 18	

	L S D at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Nitrogen (B)	0 23	0 19	0 11
A X B	NS	NS	NS
Spray (C)	0 0001	0 0001	NS
A X C	NS	NS	NS
B X C	NS	0 0009	0 0002
A X B X C	NS	NS	NS

Table 139. Pooled analysis of leaf fresh weight in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)											
	80				100				120			
	Ethrel concentration (µL/L)											
	0	100	200	Mean	0	100	200	Mean	0	100	200	Mean
	Irrigated				Irrigated				Irrigated			
N_0	34.67	41.34	47.34	41.12	25.26	30.58	35.26	30.37	12.32	16.17	20.02	16.17
N_{40}	49.77	56.22	63.45	56.48	36.26	41.43	47.50	41.73	18.41	22.41	26.51	22.45
N_{60}	56.08	64.43	72.37	64.29	44.14	50.39	56.48	50.34	22.86	27.09	31.70	27.22
N_{80}	66.77	75.38	82.06	74.74	52.82	59.11	64.39	58.77	28.22	32.37	36.66	32.42
	Non-Irrigated				Non-Irrigated				Non-Irrigated			
N_0	23.84	29.24	34.35	29.14	16.26	21.40	26.12	21.26	6.96	9.69	12.13	9.59
N_{40}	33.56	38.66	43.94	38.72	24.11	28.94	34.14	29.06	11.05	13.55	16.27	13.62
N_{60}	37.30	43.02	48.34	42.89	28.10	33.25	38.38	33.24	14.07	16.95	19.76	16.93
N_{80}	41.34	47.15	52.74	47.08	32.13	36.87	42.16	37.06	17.66	20.16	23.02	20.28
Mean	42.92	49.43	55.57		32.38	37.75	43.05		16.44	19.80	23.26	

	L.S.D. at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Nitrogen (B)	0.52	0.24	0.11
A X B	NS	NS	NS
Spray (C)	0.002	0.0002	NS
A X C	NS	NS	NS
B X C	0.043	0.003	0.0004
A X B X C	NS	NS	NS

Table 140. Pooled analysis of leaf turgid weight in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)											
	80				100				120			
	Ethrel concentration (µL/L)											
	0	100	200	Mean	0	100	200	Mean	0	100	200	Mean
	Irrigated				Irrigated				Irrigated			
N_0	53.05	59.71	65.46	59.41	45.33	50.34	54.29	49.99	25.20	29.25	33.20	29.22
N_{40}	70.30	76.37	83.68	76.78	58.61	63.27	69.07	63.65	33.38	37.56	41.81	37.58
N_{60}	76.09	84.79	92.77	84.55	68.18	74.18	79.95	74.10	39.40	43.83	48.76	44.00
N_{80}	86.54	94.90	101.32	94.25	77.42	83.16	87.77	82.78	46.31	50.50	54.89	50.57
	Non-Irrigated				Non-Irrigated				Non-Irrigated			
N_0	46.46	52.46	57.71	52.21	37.93	43.63	48.66	43.41	19.23	23.83	27.77	23.61
N_{40}	58.70	63.98	69.30	63.99	48.36	53.55	59.01	53.64	26.07	29.96	34.28	30.10
N_{60}	62.29	68.47	74.08	68.28	53.41	59.05	64.47	58.98	31.37	36.24	40.32	36.10
N_{80}	66.66	72.58	78.27	72.50	58.53	63.24	69.13	63.62	37.55	41.09	45.16	41.27
Mean	65.01	71.66	77.82		55.97	61.30	66.54		32.31	36.53	40.92	

	L.S.D. at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Nitrogen (B)	0.38	0.35	0.21
A X B	NS	NS	NS
Spray (C)	0.001	0.001	0.0002
A X C	NS	NS	NS
B X C	0.018	0.019	NS
A X B X C	NS	NS	NS

Table 141. Pooled analysis of relative water content in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)											
	80				100				120			
	Ethrel concentration (µL/L)											
	0	100	200	Mean	0	100	200	Mean	0	100	200	Mean
	Irrigated				Irrigated					Irrigated		
N_0	59.02	63.53	67.04	63.20	48.84	53.97	58.43	53.75	40.36	47.96	52.53	46.95
N_{40}	65.38	68.57	71.12	68.36	55.45	59.25	62.88	59.19	48.22	52.74	56.66	52.54
N_{60}	68.74	71.32	73.66	71.24	58.63	62.03	65.00	61.88	51.29	55.20	58.11	54.87
N_{80}	72.66	75.32	77.13	75.04	62.51	65.60	68.12	65.41	54.28	57.58	58.76	56.87
	Non-Irrigated				Non-Irrigated				26.35	Non-Irrigated		
N_0	43.40	47.71	52.02	47.80	34.00	40.56	45.40	39.99	32.70	31.16	34.28	30.60
N_{40}	49.70	53.16	56.41	53.09	41.71	46.06	50.12	45.96	35.14	36.17	38.62	35.83
N_{60}	52.71	55.88	58.52	55.70	44.71	48.58	52.02	48.44	38.02	37.84	40.32	37.77
N_{80}	54.97	58.23	60.46	57.89	47.10	50.69	53.59	50.46	40.79	40.27	42.43	40.24
Mean	58.32	61.72	64.54		49.12	53.34	56.94			44.86	47.71	

	L.S.D. at 5%		
	80	100	120
Irrigation (A)	NS	NS	NS
Nitrogen (B)	0.19	0.16	0.12
A X B	NS	NS	NS
Spray (C)	0.0002	NS	NS
A X C	NS	NS	NS
B X C	NS	NS	0.0002
A X B X C	NS	NS	NS

Table 142. Pooled analysis of rate of photosynthesis in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
	Irrigated					Irrigated		
N_0	15.10	17.47	19.87	17.48	13.14	15.58	17.94	15.55
N_{40}	18.24	20.96	24.07	21.09	16.16	19.13	22.06	19.12
N_{60}	21.00	23.93	26.64	23.86	19.23	22.25	25.27	22.25
N_{80}	23.14	25.73	28.32	25.73	22.15	24.90	27.43	24.83
	Non-Irrigated					Non-Irrigated		
N_0	13.14	15.60	17.94	15.56	11.62	14.04	16.62	14.09
N_{40}	16.19	19.06	22.14	19.13	14.45	17.23	20.38	17.35
N_{60}	19.12	22.15	25.07	22.11	17.34	20.29	23.22	20.28
N_{80}	21.89	24.71	27.21	24.60	20.19	23.26	26.14	23.20
Mean	18.48	21.20	23.91		16.78	19.59	22.38	

L.S.D. at 5%		
	80	100
Irrigation (A)	NS	NS
Nitrogen (B)	0.14	0.21
A X B	NS	NS
Spray (C)	NS	NS
A X C	NS	NS
B X C	0.0004	0.0006
A X B X C	NS	NS

Table 143. Pooled analysis of carboxylation efficiency in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
	Irrigated					Irrigated		
N_0	5.85	6.41	6.91	6.39	5.45	6.05	6.59	6.03
N_{40}	6.25	6.74	7.22	6.74	5.93	6.48	6.99	6.47
N_{60}	6.48	6.92	7.30	6.90	6.23	6.72	7.19	6.71
N_{80}	6.58	6.98	7.36	6.97	6.47	6.88	7.27	6.87
	Non-Irrigated					Non-Irrigated		
N_0	5.41	6.01	6.54	5.99	5.09	5.73	6.32	5.71
N_{40}	5.89	6.42	6.89	5.40	5.46	6.02	6.63	6.04
N_{60}	6.12	6.63	7.08	6.61	5.80	6.36	6.81	6.32
N_{80}	6.38	6.83	7.21	6.81	6.08	6.62	7.70	6.59
Mean	6.12	6.62	7.06		5.81	6.36	6.86	

	L.S.D. at 5%	
	80	100
Irrigation (A)	NS	NS
Nitrogen (B)	0.04	0.04
A X B	NS	NS
Spray (C)	NS	NS
A X C	NS	NS
B X C	NS	NS
A X B X C	NS	NS

Table 144 Pooled analysis of photosynthetic water use efficiency in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
	Irrigated					Irrigated		
N_0	35 95	39.69	43 19	38 61	32 85	37 69	41 72	37 42
N_{40}	40.35	44 59	49 12	44 69	37 58	42 82	46 94	42 45
N_{60}	43.75	47 54	51 23	47 50	41 80	46 03	49.55	44 62
N_{80}	45 37	48 86	51 49	48 57	44.30	47 59	50.79	47 56
	Non-Irrigated					Non-Irrigated		
N_0	32.85	38 06	41 72	37 54	31 38	35 98	40 54	35 97
N_{40}	37.65	42 05	47 11	42 27	35 24	40 07	45 29	40 20
N_{60}	40.68	45 51	49 16	45.12	39.41	43.80	47.39	43 53
N_{80}	43.78	47.44	50 39	47 20	42.06	45 90	49.32	45 76
Mean	40.05	44.22			38.08	42.48	46.44	

	L.S.D. at 5%	
	80	100
Irrigation (A)	NS	NS
Nitrogen (B)	0.34	0 35
A X B	NS	NS
Spray (C)	0.0002	0.0002
A X C	NS	NS
B X C	0.006	0 006
A X B X C	NS	NS

Table 145 Pooled analysis of plant water use efficiency in Experiment 3 and 4

Nitrogen	Sampling stage (days after sowing)							
	80				100			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
	Irrigated				Irrigated			
N_0	2.13	2 37	2.56	2.35	3 10	3.36	3.58	3.35
N_{40}	2.61	2 80	3.00	2 80	3 47	3.68	3.75	3.63
N_{60}	2.72	2.91	3.12	2 92	3.67	3.88	4 08	3.88
N_{80}	2.87	3 06	3 22	3 05	3 93	4 14	4 32	4 13
	Non-Irrigated				Non-Irrigated			
N_0	1 96	2 22	2.45	2 21	2 94	3 18	3 39	3 17
N_{40}	2.38	2 60	2.79	2.59	3.23	3.41	3.61	3.42
N_{60}	2.45	2.65	2 84	2 65	3 37	3.56	3 75	3.56
N_{80}	2.66	2 71	2.90	2.76	3 59	3.76	3.93	3 76
Mean	2.47	2 67	2.86		3 41	3 62	3 80	

	L.S D. at 5%	
	80	100
Irrigation (A)	NS	NS
Nitrogen (B)	0.008	0 009
A X B	NS	NS
Spray (C)	NS	NS
A X C	NS	NS
B X C	NS	NS
A X B X C	NS	NS

Table 146 Pooled analysis of pod number, seed yield and oil yield in Experiment 3 and 4

Nitrogen	Pod number				Seed yield				Oil yield			
	Ethrel concentration (µl /L)											
	0	100	200	Mean	0	100	200	Mean	0	100	200	Mean
	Irrigated				Irrigated				Irrigated			
N_0	138 00	146 33	153 33	145 89	9 19	10 67	12 05	10 64	3 27	3 94	4 60	3 94
N_{40}	159 30	166 33	173 00	166 22	12 27	13 65	15 00	13 64	4 29	4 95	5 63	4 96
N_{60}	172 67	181 67	189 00	181 44	15 03	16 58	18 07	16 56	5 12	5 85	6 61	5 86
N_{80}	190 33	197 33	203 67	197 11	18 29	19 74	21 20	19 74	6 02	6 78	7 55	6 78
	Non-Irrigated				Non-Irrigated				Non-Irrigated			
N_0	122 00	129 33	137 00	129 44	7 01	8 29	9 53	8 28	2 34	2 87	3 42	2 88
N_{40}	137 00	144 33	152 00	144 44	9 08	10 26	11 51	10 28	2 96	3 48	4 04	3 49
N_{60}	149 33	156 67	164 00	156 67	11 15	12 36	13 56	12 36	3 51	4 05	4 61	4 06
N_{80}	159 67	166 67	174 67	167 00	12 55	14 43	15 71	14 23	3 84	4 60	5 20	4 55
Mean	153 54	161 08	168 33		11 82	13 25	14 58		3 92	4 57	5 21	

	L S D at 5%		
	Pod number	Seed yield	Oil yield
Irrigation (A)	NS	NS	NS
Nitrogen (B)	0 44	0 19	0 02
A X B	NS	NS	NS
Spray (C)	0 005	0 0001	NS
A X C	NS	NS	NS
B X C	NS	NS	NS
A X B X C	NS	NS	NS

Table 147. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on leaf area plant^{-1} (cm^2) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80, 100 and 120 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	3473.67	3512.33	3493.00	4041.67	4150.33	4096.00
E_{200}	3748.33	3850.67	3795.50	4251.67	4353.33	4302.50
S_1	3383.33	3406.67	3395.00	3843.33	3973.00	3908.17
Mean	3535.11	3589.67		4045.56	4158.89	

	120		
E_0	2667.67	2676.67	2672.17
E_{200}	2840.00	2951.67	2895.84
S_1	2504.00	2654.33	2579.17
Mean	2670.56	2760.89	

	L.S.D. at 5%		
	80	100	120
Irrigation (I)	NS	NS	NS
Spray (S)	32.86	34.54	42.96
I x S	NS	NS	NS

Table 148. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on plant dry weight (g/plant) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80, 100 and 120 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	35.20	42.33	38.76	40.20	47.84	44.02
E_{200}	36.10	43.22	39.66	41.20	49.08	45.14
S_1	33.49	41.17	37.33	38.25	46.08	42.17
Mean	34.93	42.24		39.88	47.67	

	120		
E_0	45.26	53.79	49.53
E_{200}	46.39	55.32	50.86
S_1	42.70	51.58	47.14
Mean	44.79	53.56	

	L.S.D. at 5%		
	80	100	120
Irrigation (I)	NS	NS	NS
Spray (S)	0.29	0.20	0.25
I x S	NS	NS	NS

Table 149. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on rate of photosynthesis (µ mol m^{-2} s^{-1}) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	24.03	25.32	24.68	22.40	24.30	23.35
E_{200}	25.32	26.55	25.94	24.21	25.51	24.86
S_1	23.20	24.77	23.98	21.63	23.59	22.61
Mean	24.19	25.55		22.75	24.47	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0.22	0.20
I x S	NS	NS

Table 150 Effect of ethrel (E, 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on stomatal conductance (mol m^{-2} s^{-1}) of mustard (*Brassica juncea* L) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	0 51	0 52	0 52	0 49	0 51	0 50
E_{200}	0 53	0 54	0 53	0 52	0 53	0 52
S_1	0 50	0 51	0 51	0 48	0 50	0 49
Mean	0 51	0 52		0 50	0 51	

	L S D at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0 007	0 008
I x S	NS	NS

Table 151. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on internal CO_2 concentration (µ mol mol^{-1}) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	354.60	361.60	358.10	342.77	354.37	348.57
E_{200}	368.10	376.07	372.08	361.07	368.67	364.87
S_1	346.67	355.83	351.25	335.23	345.10	340.17
Mean	356.46	364.50		346.36	356.04	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	13.74	13.57
I x S	NS	NS

Table 152. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on transpiration rate (kg m^{-2} day^{-1}) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	12.72	14.11	13.42	10.52	11.69	11.10
E_{200}	12.85	14.25	13.55	10.63	11.74	11.19
S_1	12.57	13.86	13.21	10.42	11.54	10.98
Mean	12.71	14.07		10.52	11.66	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0.05	0.02
I x S	NS	NS

Table 153. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on carboxylation efficiency (%) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	6.78	7.00	6.89	6.54	6.86	6.70
E_{200}	6.88	7.06	6.97	6.70	6.92	6.81
S_1	6.69	6.96	6.83	6.45	6.83	6.64
Mean	6.78	7.01		6.56	6.87	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0.03	0.04
I x S	NS	NS

Table 154. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on photosynthetic water use efficiency (µ mol mol^{-1}) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	46.82	48.70	47.76	45.41	47.34	46.38
E_{200}	47.78	49.38	48.58	46.86	48.44	47.65
S_1	46.09	48.25	47.17	44.76	47.18	45.97
Mean	46.90	48.78		45.67	47.65	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0.42	0.42
I x S	NS	NS

Table 155. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on plant water use efficiency (mg g^{-1}) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	2.76	3.00	2.88	3.82	4.09	3.96
E_{200}	2.81	3.04	2.92	3.88	4.18	4.03
S_1	2.68	2.97	2.82	3.67	3.99	3.83
Mean	2.75	3.00		3.79	4.09	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0.02	0.02
I x S	NS	NS

Table 156. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on 1-aminocyclopropane-1-carboxylic acid content (ACC) (η mol g^{-1} fresh weight) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	30.86	25.88	28.37	36.17	30.30	33.23
E_{200}	35.21	29.79	32.50	40.16	35.52	37.84
S_1	26.46	22.09	24.28	31.43	26.33	28.88
Mean	30.84	25.92		35.92	30.72	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	4.03	4.36
I x S	NS	NS

Table 157. Effect of ethrel (E; 200μL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on ACC oxidase (η L g^{-1} fresh weight h^{-1}) of mustard (*Brassica juncea* L) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	124.00	108.13	116.07	135.49	125.71	130.60
E_{200}	132.97	117.50	125.23	149.53	134.88	142.20
S_1	109.09	91.93	100.51	121.88	111.15	116.51
Mean	122.02	105.85		135.63	123.91	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	8.25	10.93
I x S	NS	NS

Table 158. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on ethylene evolution (ηl h^{-1} $plant^{-1}$) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	31.88	27.66	29.77	35.88	32.14	34.01
E_{200}	36.92	31.17	34.05	39.99	35.55	37.77
S_1	25.64	21.92	23.78	30.29	26.07	28.18
Mean	31.48	26.92		35.39	31.25	

	L.S.D. at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	2.97	2.83
I x S	NS	NS

Table 159 Effect of ethrel (E, 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on nitrate reductase activity (µ mol NO_2^- g^{-1} h^{-1}) of mustard (*Brassica juncea* L) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80 and 100 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	0.59	0.68	0 63	0 52	0 59	0 56
E_{200}	0 64	0 73	0 69	0 57	0 65	0 61
S_1	0 56	0 64	0 60	0 49	0 56	0 52
Mean	0 60	0 68		0 53	0 60	

	L S D at 5%	
	80	100
Irrigation (I)	NS	NS
Spray (S)	0 013	0 014
I x S	NS	NS

Table 160 Effect of ethrel (E, 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on N content (%) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80, 100 and 120 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	2.81	2.92	2.87	2.46	2.63	2 54
E_{200}	2.84	3 01	2.93	2.52	2.69	2.60
S_1	2 73	2 89	2 81	2 42	2 57	2 50
Mean	2.79	2 94		2 47	2.63	

	120		
E_0	2.11	2 28	2.20
E_{200}	2.17	2.31	2.24
S_1	2.05	2.26	2.16
Mean	2.11	2 28	

	L.S.D. at 5%		
	80	100	120
Irrigation (I)	NS	NS	NS
Spray (S)	0 02	0 01	0 01
I x S	NS	NS	NS

Table 161. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on N accumulation (mg plant^{-1}) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions at 80, 100 and 120 DAS

Treatment	Sampling stage (days after sowing)					
	80			100		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	988.00	1237.00	1112.50	987.67	1258.00	1122.83
E_{200}	1025.33	1300.67	1163.00	1038.33	1318.67	1178.50
S_1	913.00	1189.67	1051.33	925.67	1184.33	1055.00
Mean	975.44	1242.44		983.89	1253.67	

	120		
E_0	956.67	1228.67	1092.67
E_{200}	1008.33	1277.67	1143.00
S_1	875.33	1167.33	1021.33
Mean	946.78	1224.56	

	L.S.D at 5%		
	80	100	120
Irrigation (I)	NS	NS	NS
Spray (S)	8.51	6.98	6.25
I x S	NS	NS	NS

Table 162 Effect of ethrel (E, 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight (g) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions

Treatment	Pods plant^{-1}			Seeds pod^{-1}		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	165.00	195.00	180.00	14 78	16 93	15.86
E_{200}	169.67	198.67	184.17	14.92	17 15	16.03
S_1	160.00	189.67	174.83	14.22	16 40	15.31
Mean	164.89	194.44		14 64	16 83	

	1000 seed weight		
E_0	4.65	4 68	4.67
E_{200}	4.68	4.74	4.71
S_1	4.63	4.65	4.64
Mean	4.65	4.69	

	L.S D at 5%		
	Pods plant^{-1}	Seeds pod^{-1}	1000 seed weight
Irrigation (I)	NS	NS	NS
Spray (S)	3.50	0.06	0.02
I x S	NS	NS	NS

Table 163 Effect of ethrel (E, 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on seed yield (q ha ^{1}), biological yield (q ha ^{1}) and harvest index (%) of mustard (*Brassica juncea* L) grown with basal 80kg N/ha under irrigated and non-irrigated conditions

Treatment	Seed yield			Biological yield		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	14 19	19 32	16 75	56 58	67 36	61 97
E_{200}	14 81	20 17	17 49	57 99	69 15	63 57
S_1	13 16	18 07	15 61	53 37	64 48	58 93
Mean	14 05	19 18		55 98	67 00	

	Harvest index		
E_0	25 07	28 68	26 88
E_{200}	25 53	29 17	27 35
S_1	24.65	28 02	26 33
Mean	25 09	28 62	

	L S D at 5%		
	Seed yield	Biological yield	Harvest index
Irrigation (I)	NS	NS	NS
Spray (S)	0 12	0 28	0 10
I x S	NS	NS	NS

Table 164. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on seed nitrogen content (mg g^{-1} $seed^{-1}$), nitrogen harvest index and nitrogen yield potential of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions

Treatment	Seed nitrogen content			Nitrogen harvest index		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	47.20	56.60	51.90	0.05	0.05	0.05
E_{200}	49.07	59.17	54.12	0.05	0.05	0.05
S_1	45.17	55.17	50.17	0.05	0.05	0.05
Mean	47.14	56.98		0.05	0.05	

	Nitrogen yield potential		
E_0	2.36	2.83	2.60
E_{200}	2.45	2.96	2.70
S_1	2.26	2.76	2.51
Mean	2.36	2.85	

	L.S.D. at 5%		
	Seed nitrogen content	Nitrogen harvest index	Nitrogen yield potential
Irrigation (I)	NS	NS	NS
Spray (S)	0.39	NS	0.02
I x S	NS	NS	NS

Table 165. Effect of ethrel (E; 200µL/L) or silver thiosulphate (S; 1mM) at 60d after sowing (DAS, flowering stage) on oil yield (q ha^{-1}) and oil content (%) of mustard (*Brassica juncea* L.) grown with basal 80kg N/ha under irrigated and non-irrigated conditions

Treatment	Oil yield			Oil content		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	4.46	6.55	5.50	31.46	33.89	32.67
E_{200}	4.74	6.96	5.85	32.06	34.53	33.30
S_1	3.97	5.82	4.89	30.18	32.20	31.19
Mean	4.39	6.44		31.23	33.54	

L.S.D. at 5%

	Oil yield	Oil content
Irrigation (I)	NS	NS
Spray (S)	0.05	0.17
I x S	NS	NS

Table 166 Effect of ethrel (E, 200µL/L) or silver thiosulphate (S, 1mM) at 60d after sowing (DAS, flowering stage) on acid value, iodine value and saponification value of mustard (*Brassica juncea* L) grown with basal 80kg N/ha under irrigated and non-irrigated conditions

Treatment	Acid value			Iodine value		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
E_0	2 52	3 00	2 76	93 86	96 72	95 29
E_{200}	2 69	3 24	2 97	94 89	97 97	96 43
S_1	2 14	2 66	2 40	92 63	95 34	93 98
Mean	2 45	2 97		93 79	96 68	

	Saponification value		
E_0	153 45	158 44	155 95
E_{200}	156 06	160 53	158 30
S_1	151 54	155 23	153 39
Mean	153 68	158 07	

L S D at 5%

	Acid value	Iodine value	Saponification value
Irrigation (I)	NS	NS	NS
Spray (S)	0 06	0 17	0 53
I x S	NS	NS	NS

Table 167. Linear regression values of plant characteristics in Experiment 1 at 80 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.994**	1.000							
Specific leaf weight	0.968**	0.947**	1.000						
Specific leaf area	0.973**	0.951**	0.996**	1.000					
Leaf dry weight	0.997**	0.996**	0.951**	0.955**	1.000				
Plant N content	0.865**	0.860**	0.897**	0.866**	0.866**	1.000			
Pod number	0.973**	0.960**	0.976**	0.972**	0.965**	0.908**	1.000		
Seed number	0.900**	0.877**	0.851**	0.850**	0.912**	0.837**	0.893**	1.000	
Seed yield	0.965**	0.946**	0.935**	0.936**	0.967**	0.876**	0.969**	0.974**	1.000

Table 168. Linear regression values of plant characteristics in Experiment 1 at 100 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Paramcter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.997**	1.000							
Specific leaf weight	0.943**	0.932**	1.000						
Specific leaf area	0.954**	0.945**	0.998**	1.000					
Leaf dry weight	0.996**	0.995**	0.911**	0.924**	1.000				
Plant N content	0.848**	0.848**	0.866**	0.877**	0.831**	1.000			
Pod number	0.961**	0.964**	0.953**	0.965**	0.944**	0.919**	1.000		
Seed number	0.969**	0.972**	0.946**	0.962**	0.986**	0.795**	0.893**	1.000	
Seed yield	0.995**	0.998**	0.923**	0.938**	0.994**	0.861**	0.969**	0.974**	1.000

Table 169. Linear regression values of plant characteristics in Experiment 1 at 120 DAS (* significant at $P < 0.05$, ** significant at $P < 0.01$)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.998**	1.000							
Specific leaf weight	0.914**	0.900**	1.000						
Specific leaf area	0.895**	0.878**	0.992**	1.000					
Leaf dry weight	0.996**	0.997**	0.880**	0.858**	1.000				
Plant N content	0.828**	0.817**	0.941**	0.952**	0.791**	1.000			
Pod number	0.940**	0.937**	0.961**	0.956**	0.917**	0.953**	1.000		
Seed number	0.983**	0.990**	0.843**	0.813**	0.993**	0.758*	0.893**	1.000	
Seed yield	0.992**	0.993**	0.929**	0.910**	0.985**	0.869**	0.969**	0.974**	1.000

Table 170. Linear regression values of plant characteristics in Experiment 2 at 80 DAS (* significant at $P < 0.05$, ** significant at $P < 0.01$)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.995**	1.000							
Specific leaf weight	0.929**	0.902**	1.000						
Specific leaf area	0.933**	0.904**	0.999**	1.000					
Leaf dry weight	0.994**	0.998**	0.889**	0.893**	1.000				
Plant N content	0.678*	0.665*	0.770**	0.771**	0.649*	1.000			
Pod number	0.996**	0.991**	0.910**	0.916**	0.995**	0.677*	1.000		
Seed number	0.923**	0.916**	0.771**	0.780**	0.939**	0.510^{NS}	0.940**	1.000	
Seed yield	0.991**	0.985**	0.891**	0.898**	0.992**	0.654*	0.996**	0.960**	1.000

Table 171. Linear regression values of plant characteristics in Experiment 2 at 100 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.996**	1.000							
Specific leaf weight	0.890**	0.861**	1.000						
Specific leaf area	0.865**	0 832**	0.995**	1 000					
Leaf dry weight	0.996**	0.998**	0.849**	0.820**	1.000				
Plant N content	0.839**	0.821**	0.929**	0.915**	0.808**	1.000			
Pod number	0.994**	0.985**	0.923**	0.899**	0.984**	0.863**	1.000		
Seed number	0.956**	0.946**	0.789**	0.762*	0.961**	0.738*	0.940**	1.000	
Seed yield	0.995**	0.985**	0.909**	0.883**	0.986**	0.848**	0.996**	0.960**	1.000

Table 172 Linear regression values of plant characteristics in Experiment 2 at 120 DAS (* significant at P < 0.05, ** significant at P < 0 01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1 000								
Plant dry weight	0.995**	1.000							
Specific leaf weight	0 884**	0.851**	1.000						
Specific leaf area	0 896**	0 864**	0.996**	1.000					
Leaf dry weight	0.996**	0.998**	0.844**	0.857**	1 000				
Plant N content	0.944**	0.940**	0.908**	0 912**	0 935**	1 000			
Pod number	0 990**	0 978**	0 923**	0 936**	0 977**	0 960**	1 000		
Seed number	0 968**	0 966**	0 782**	0.801**	0.974**	0 867**	0 940**	1.000	
Seed yield	0.996**	0.986**	0.907**	0.920**	0.986**	0 947**	0.996**	0.960**	1.000

Table 173. Linear regression values of plant characteristics in Experiment 3 at 80 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.870**	1.000							
Specific leaf weight	0.889**	0.992**	1.000						
Specific leaf area	0.902**	0.992**	0.998**	1.000					
Leaf dry weight	0.916**	0.985**	0.981**	0.988**	1.000				
Plant N content	0.942**	0.973**	0.977**	0.986**	0.995**	1.000			
Pod number	0.927**	0.962**	0.964**	0.973**	0.989**	0.992**	1.000		
Seed number	0.932**	0.935**	0.941**	0.954**	0.975**	0.983**	0.996**	1.000	
Seed yield	0.934**	0.929**	0.933**	0.948**	0.974**	0.981**	0.993**	0.999**	1.000

Table 174. Linear regression values of plant characteristics in Experiment 3 at 100 DAS (* significant at P < 0.05, ** significant at P < 0 01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.983**	1.000							
Specific leaf weight	0.990**	0.990**	1.000						
Specific leaf area	0.994**	0.988**	0.997**	1.000					
Leaf dry weight	0.999**	0.986**	0.991**	0.994**	1.000				
Plant N content	0.995**	0.973**	0.985**	0.993**	0.992**	1.000			
Pod number	0.997**	0.986**	0.989**	0.991**	0.998**	0.989**	1.000		
Seed number	0.994**	0.968**	0.978**	0.983**	0.993**	0.989**	0.996**	1.000	
Seed yield	0.994**	0.964**	0.975**	0.983**	0.991**	0.991**	0.993**	0.999**	1.000

Table 175. Linear regression values of plant characteristics in Experiment 3 at 120 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.990**	1.000							
Specific leaf weight	0.971**	0.982**	1 000						
Specific leaf area	0.981**	0.987**	0.998**	1.000					
Leaf dry weight	0.999**	0.992**	0.973**	0.983**	1.000				
Plant N content	0.830**	0.879**	0.931**	0.915**	0.836**	1.000			
Pod number	0.993**	0.995**	0.979**	0.985**	0.995**	0.863**	1.000		
Seed number	0.993**	0.986**	0.962**	0.971**	0.994**	0.822**	0.996**	1.000	
Seed yield	0.996**	0.984**	0.957**	0.968**	0.996**	0.807**	0.993**	0.999**	1.000

Table 176. Linear regression values of plant characteristics in Experiment 4 at 80 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.978**	1.000							
Specific leaf weight	0.996**	0.984**	1.000						
Specific leaf area	0.998**	0.973**	0.998**	1.000					
Leaf dry weight	0.998**	0.989**	0.996**	0.994**	1.000				
Plant N content	0.986**	0.941**	0.982**	0.990**	0.976**	1.000			
Pod number	0.981**	0.937**	0.975**	0.984**	0.971**	0.986**	1.000		
Seed number	0.937**	0.862**	0.924**	0.942**	0.916**	0.962**	0.981**	1.000	
Seed yield	0.963**	0.897**	0.950**	0.965**	0.946**	0.974**	0.989**	0.989**	1.000

Table 177. Linear regression values of plant characteristics in Experiment 4 at 100 DAS (* significant at $P < 0.05$, ** significant at $P < 0.01$)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.994**	1.000							
Specific leaf weight	0.995**	0.993**	1.000						
Specific leaf area	0.998**	0.993**	0.997**	1.000					
Leaf dry weight	0.999**	0.997**	0.996**	0.998**	1.000				
Plant N content	0.977**	0.991**	0.986**	0.981**	0.982**	1.000			
Pod number	0.992**	0.981**	0.976**	0.986**	0.990**	0.950**	1.000		
Seed number	0.958**	0.932**	0.930**	0.946**	0.951**	0.881**	0.981**	1.000	
Seed yield	0.977**	0.954**	0.957**	0.970**	0.971**	0.914**	0.989**	0.989**	1.000

Table 178. Linear regression values of plant characteristics in Experiment 4 at 120 DAS (* significant at P < 0.05, ** significant at P < 0.01)

Parameter	Leaf area	Plant dry weight	Specific leaf weight	Specific leaf area	Leaf dry weight	Plant N content	Pod number	Seed number	Seed yield
Leaf area	1.000								
Plant dry weight	0.987**	1.000							
Specific leaf weight	0.986**	0.987**	1.000						
Specific leaf area	0.990**	0.986**	0.999**	1.000					
Leaf dry weight	0.999**	0.991**	0.988**	0.990**	1.000				
Plant N content	0.978**	0.940**	0.960**	0.967**	0.973**	1.000			
Pod number	0.993**	0.999**	0.989**	0.989**	0.995**	0.950**	1.000		
Seed number	0.990**	0.975**	0.961**	0.964**	0.989**	0.963**	0.981**	1.000	
Seed yield	0.993**	0.984**	0.979**	0.983**	0.992**	0.967**	0.989**	0.989**	1.000

Table 179. Effect of ethrel spray at 60d (post flowering stage) on nitrogen uptake efficiency (kg ha^{-1}), nitrogen utilization efficiency (kg ha^{-1}) and nitrogen use efficiency (kg ha^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Nitrogen uptake efficiency				Nitrogen utilization efficiency			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_{40}	0.43	0.48	0.55	0.49	11.56	11.26	10.97	11.26
N_{60}	0.44	0.51	0.57	0.51	12.47	12.09	11.79	12.12
N_{80}	0.48	0.54	0.59	0.54	13.04	12.56	12.33	12.64
Mean	0.45	0.51	0.57		12.36	11.97	11.70	

	Nitrogen use efficiency				L.S.D. at 5%		
N_{40}	4.93	5.44	6.00	5.46		Nitrogen uptake efficiency	Nitrogen utilization efficiency	Nitrogen use efficiency
N_{60}	5.53	6.13	6.72	6.12				
N_{80}	6.26	6.83	7.27	6.79	Spray (S)	0.004	0.076	0.046
Mean	5.57	6.13	6.66		Nitrogen (N)	0.004	0.076	0.046
					S x N	0.008	NS	0.080

Table 180. Effect of ethrel spray at 60d (post flowering stage) on nitrogen uptake efficiency (kg ha^{-1}), nitrogen utilization efficiency (kg ha^{-1}) and nitrogen use efficiency (kg ha^{-1}) of mustard (*Brassica juncea* L.) cultivar Alankar grown with four basal levels of nitrogen

Nitrogen (kg/ha)	Nitrogen uptake efficiency				Nitrogen utilization efficiency			
	Ethrel concentration (µL/L)							
	0	100	200	Mean	0	100	200	Mean
N_{40}	0.29	0.34	0.40	0.34	12.41	11.84	11.25	11.84
N_{60}	0.32	0.38	0.44	0.38	12.81	11.92	11.28	12.00
N_{80}	0.36	0.41	0.46	0.41	11.93	11.92	11.48	11.78
Mean	0.32	0.38	0.43		12.38	11.89	11.34	

	Nitrogen use efficiency				L.S.D. at 5%		
					Nitrogen uptake efficiency	Nitrogen utilization efficiency	Nitrogen use efficiency
N_{40}	3.60	4.02	4.56	4.06			
N_{60}	4.06	4.49	4.93	4.49			
N_{80}	4.25	4.89	5.28	4.81	Spray (S)	0.004	0.374	0.127
Mean	3.97	4.47	4.92		Nitrogen (N)	0.004	NS	0.127
					S x N	0.007	NS	NS